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USDA FOREST SERVICE GENERAL TECHNICAL REPORT PNW-26

SENSITIVITY OF ALLOWABLE CUTS TO INTENSIVE MANAGEMENT

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ABSTRACT

A sensitivity analysis of allowable cuts on two BLM master units shows that even-flow allowable cuts depend primarily on:

(1) assumed long-term growth potential,
(2) period that growth increases must be cumulated before they can be removed from the stands on which they occur, and
(3) amount and age-class distribution of the initial inventory.

Current allowable cut levels respond relatively more to changes in long-term growth where:

(1) the initial inventory is higher,
(2) the age classes are more evenly distributed,
(3) the growth increases can be cut sooner from the stands on which they occur, and
(4) growth increases are smaller in proportion to the allowable cut.

Current allowable cut levels respond relatively more to changes in inventory or short-term growth where:

(1) the initial inventory is lower, and
(2) the inventory is less evenly distributed.

Although these results apply to even-flow allowable cuts, they should be regarded as rough approximations when applied to allowable cuts with less restrictive periodic flow constraints.

KEYWORDS: Allowable cut, management (forest).

CONTENTS

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INTRODUCTION

The Bureau of Land Management (1970), the U.S. Forest Service,[1] and at least one major State forest management agency (Chambers and Pierson 1973) have all adopted some variant of even flow of timber volume as the basis for their timber harvesting programs. Constraints on the relation of harvests between time periods have a great impact on the timing and magnitude of benefits that result from other decisions such as growth-stimulating investments and changes in the land base devoted to timber production. Therefore, these and other agencies or firms for whom some variant of even flow is a possible policy, need answers to the following questions:

1. How will the allowable cut be changed by growth-stimulating treatments? Will the change in allowable cut equal the change in annual growth attributable to the treatment?
2. Will the cut continue to change in proportion to changes in annual growth as these successive changes are made?
3. How are answers to these questions affected by the volume and age-class distribution of initial inventory?

Others have argued the merits of even flow (Waggener 1969, Keane 1972) and the appropriate use of the change in allowable cut in making investment decisions (Schweitzer, Sassaman, and Schallau 1972; Teeguarden 1973; Schweitzer, Sassaman, and Schallau 1973; and Lundgren 1973). We make no judgment in our paper about either issue. We simply believe that because several important public forest management agencies are committed to this type of regulation model, it is important to understand its implications, regardless of the specific way in which this information is used.

Partial answers to the above questions are available as the result of extensive sensitivity testing of allowable cut levels for two Bureau of Land Management (BLM) management units.[2] These tests were made, using the SIMAC model (Sassaman, Holt, and Bergsvik 1972) to determine the impact on allowable cut of various changes in management intensity, area base, and units of measure.

However, an even-flow allowable cut model can be viewed as one end of a continuum of models with constraints on the relation of harvests between time periods. Therefore, although we may make quantitative estimates of the importance of various assumptions, we may be safe only in specifying the direction of change when generalizing to allowable cut models with less restrictive periodic flow constraints.

THE DATA BASE

The two forests selected for analysis are the 100,000-acre Columbia and Alsea-Rickreall Master Units of the Bureau of Land Management in western Oregon. While these forests are quite similar in estimated productive potential, they differ markedly in present age-class distributions and standing volumes of timber. The Columbia contains slightly more than 3 billion board feet of standing timber with only a minor old-growth component; the Alsea-Rickreall has nearly 4-1/2 billion board feet with approximately one-fourth over 100 years of age.[3]

[1] USDA Forest Service, Emergency Directive No. 16 (F.S. Manual; Chapter 2410, Timber Management Plans), May 1, 1973.

[2] Dennis L. Schweitzer and Roger D. Fight. An analysis of selected assumptions basic to "an allowable cut plan for western Oregon." Report submitted to Bureau of Land Management, Portland, Oregon, Aug. 4, 1972.

[3] All board-foot volumes are International 1/8-inch rule. Inventory figures are obtained by multiplying the age classes by the BLM yield equation volumes.

Figure 1 shows the age-class distribution of a fully regulated forest with a rotation of 85 years plus a 5-year regeneration lag. The diagonal line is a continuous age class representation while the bars represent stands classified into 10-year age classes. Figure 2 shows how the two BLM Master Units compare to a fully regulated forest.

In its 1970 allowable-cut plan (Bureau of Land Management 1970), the BLM calculated even-flow annual allowable cuts of 95 million board feet for the Columbia and 96 million board feet for the Alsea-Rickreall units. These cuts were based on the following assumptions:

--full regeneration of harvested stands will require 3 years from time of harvest,

--precommercial and commercial thinning will ultimately encompass about one-fourth of the area,

--the remaining three-fourths of the area will have increased yield of 11 percent because it will be of genetically improved stock,

--no fertilization will be done,

--the timber producing land base will remain constant, after minor adjustments in the first four decades.

By altering these assumptions, we are able to show the importance of long-term growth[4/] and the extent and age-class distribution of the initial inventory in determining allowable cuts.

[4/] "Long-term growth" is shorthand for growth that, once initiated, continues throughout the remainder of the period used in the allowable-cut calculation.

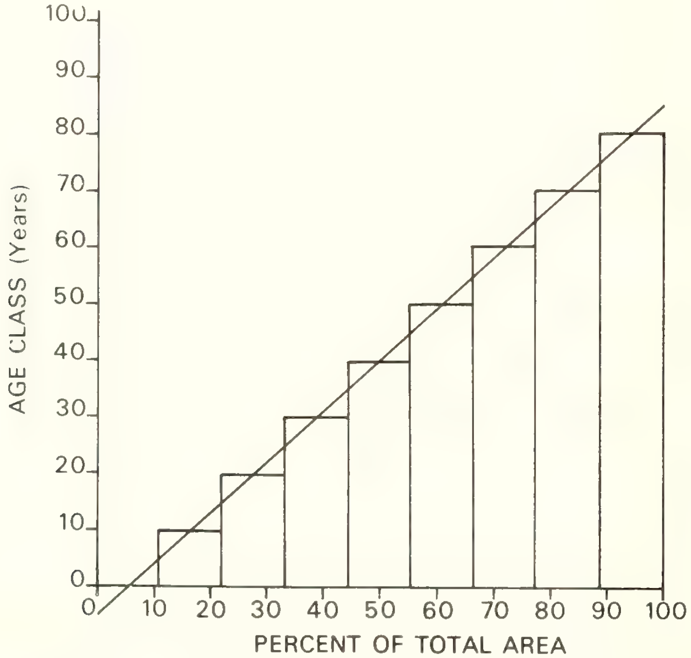
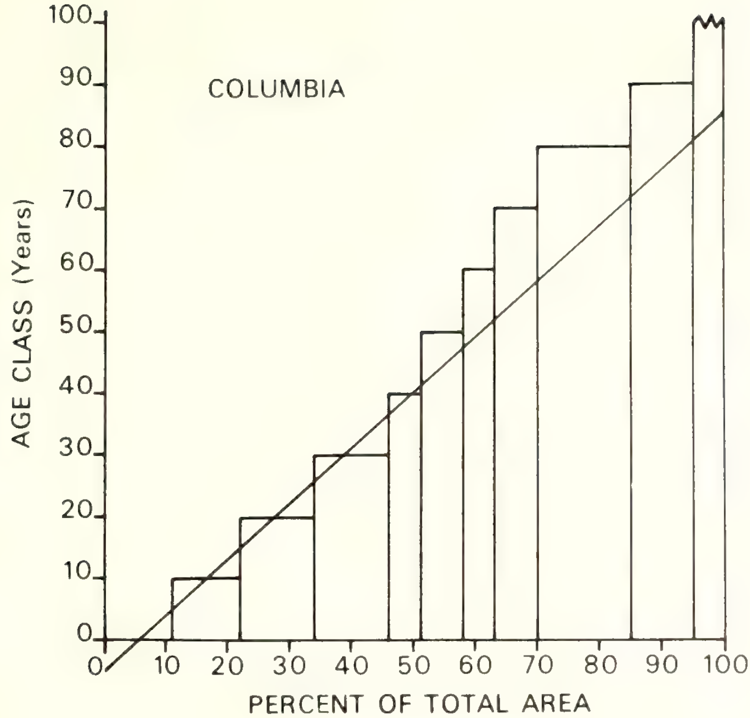


Figure 1.--Percent of area by age class for a fully regulated forest with rotation of 85 years plus a 5-year regeneration period.



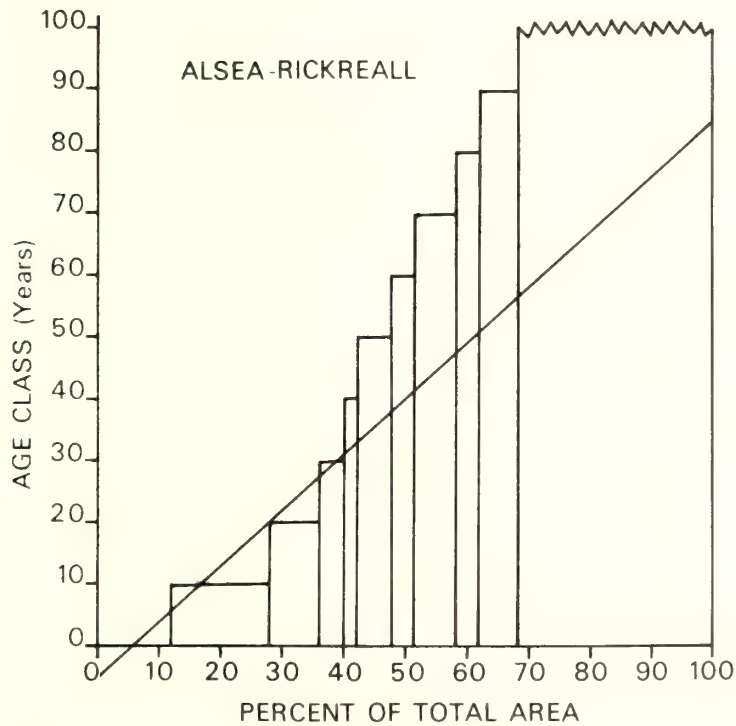


Figure 2.--Percent of area by age class for Columbia and Alsea-Rickreall Master Units.

RESPONSE OF ALLOWABLE CUTS TO NEW ASSUMPTIONS

Regeneration Period

In a forest with a normal distribution of age classes, shifting yields by 2 years in an 80-year rotation would change the mean annual increment of the forest by 2/80 or 2.5 percent. This hypothetical change in long-term growth is almost exactly reflected in the changes in allowable cut that would occur on the Alsea-Rickreall if the regeneration period were to be varied from the baseline 3 years to 1 year and to 5 years, as shown in table 1. But a much smaller change would be induced on the Columbia.

This provides data for answering each of the three questions we posed: (1) Yes, the increase in allowable cut may approach the increase in growth attributable to the new practice. (2) Yes, the increases may be proportional as successive increments of growth are added. (3) However, the above occurs when there is a large old-growth component to the inventory and is less likely to occur with a smaller inventory.

Thinning Yield

We tested the effect on the allowable cut of changes in the assumed yield response to thinning. We reduced the yield increases attributable to thinning by 25 percent and by 50 percent for both the "commercial thin only" regime and the "precommercial plus commercial thin" regime. For example, with the 50-percent reduction, the cumulative production to age 85 from stands that are commercially thinned from age 30 is reduced from 93 M bm/acre to 73 M bm/acre; the cumulative production to age 85 from stands both precommercially and commercially thinned is reduced from 102 M bm/acre to 78 M bm/acre.

The top half of table 2 shows the results for each management unit when the response to the "commercial thin only" regime is reduced 25 percent and 50 percent. Because commercial thinning without precommercial thinning occurs only in the first few decades, the change in this yield does not change the long-term growth

Table 1.--*Effect on annual allowable cut of changing regeneration period*

Years change from baseline regeneration period	Change in annual allowable cut	
	Columbia Master Unit (3 percent > 100 years)	Alsea-Rickreall Master Unit (28 percent > 100 years)
	Percent	
2 less	+1.4	+2.3
2 more	-1.9	-2.3

Table 2.--*Effect on annual allowable cut of reducing increases in yields attributed to thinning*

Change in response to thinning	Reduction in annual allowable cut	
	Columbia Master Unit (3 percent > 100 years)	Alsea-Rickreall Master Unit (28 percent > 100 years)
	Percent	
Response to commercial thinning:[1]		
Down 25 percent	1.4	0.1
Down 50 percent	2.8	.2
Response to commercial and precommercial thinning:[2]		
Down 25 percent	2.4	4.5
Down 50 percent	4.8	8.7

1/ About twice as many stands will go into the "commercial thin only" regime on the Columbia Master Unit as on the Alsea-Rickreall.

2/ About 1-1/2 times as many stands will go into the "precommercial plus commercial thin" regime on the Alsea-Rickreall Master Unit as on the Columbia.

potential and is similar to a change in initial inventory; i.e., the effect is to change the amount of timber available for harvest in the first few decades. Because of the greater acreage of thinnable stands, about twice as many stands are thinned on the Columbia as on the Alsea-Rickreall. The reduction in allowable cut, however, is much more than twice that on the Alsea-Rickreall. Thus, we see that a change affecting the growth and yield of already existing stands (essentially an inventory change) has the greater impact on the area where inventory is relatively less abundant. We see on both areas that the response is directly proportional to the magnitude of the assumed change.

The bottom half of table 2 shows the results for each management unit when the response to the "precommercial plus commercial thin" regime is reduced 25 percent and 50 percent. Changes in yields from stands that have been both precommercially and commercially thinned are primarily changes in long-term growth because precommercial thinning is phased in over decades two to seven and continued throughout the planning period. The Alsea-Rickreall will have about 1-1/2 times as many acres precommercially thinned as the Columbia (29 percent of the area vs. 19 percent). The reduction on the Alsea-Rickreall, however, is almost twice as much, demonstrating that the allowable cut responds more to changes in long-term growth where there is relatively more inventory. Here again we see that with successive changes, the impact on the allowable cut is almost directly proportional to the assumed change in growth.

Genetics

Genetic improvement applies only to stands that will not be thinned; this will ultimately be about 80 percent of the area on the Columbia and 70 percent of the Alsea-Rickreall. Planting with genetically improved stock will be phased in during the second and third decades.

We tested the effect on the allowable cut of changes in the assumed yield response to genetically improved stock. First we increased the response 5 percent; then we decreased the response 5 and 10 percent.

The maximum change in cut that could be expected is the percentage change in yield times the proportion of acres treated. For the 5-percent change in yield, this would be approximately $5 \times 0.75 = 3.7$ percent. Figure 3 shows that on both units the change in cut is less than the change in growth. This demonstrates that even the ability of a forest with substantial old-growth to sustain an increase in allowable cut is limited; where the growth increase must be cumulated for long periods before it can be harvested from the stands on which it occurs, the increase in allowable cut is less than the increase in growth.

Figure 3 demonstrates the same kind of proportionality that we saw when the regeneration lag was varied. On the Alsea-Rickreall, which has an abundance of old growth, changes in cut are proportional to changes in growth. On the Columbia, as we added successive increments of growth, the change in cut became proportionately less--so much so, in fact, that additional anticipated increases in response to genetics would not likely have much impact at all on the allowable cut.

Adding Fertilization

We tested the effect of fertilizing at 10-year intervals all stands that would be thinned, using a 15-percent increase in periodic increment. For example, the cumulative production at age 80 for

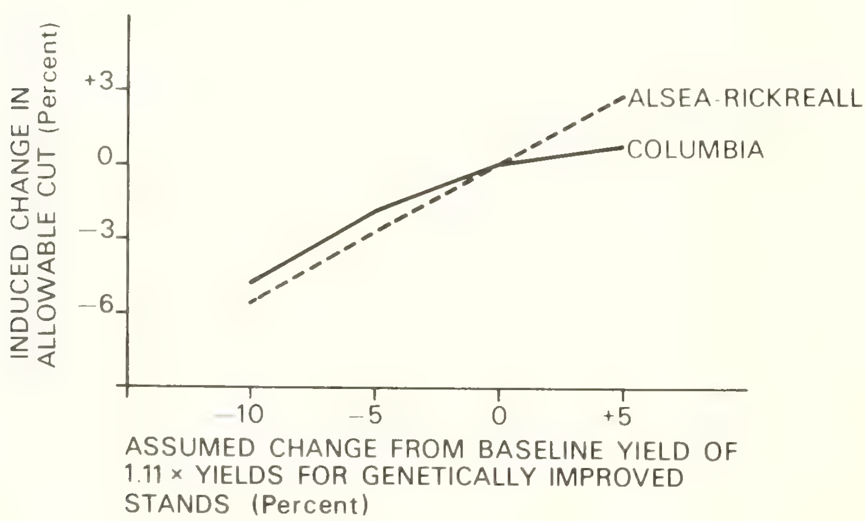


Figure 3.--Effect on allowable cut of changing increases in yields attributed to genetic improvement.

precommercially and commercially thinned stands with and without fertilizer would be 116 M bm and 102 M bm/acre, respectively.

Since the Columbia would have more stands fertilized initially (it has more "commercial thin only" acres) but the Alsea-Rickreall would have more stands fertilized in the future (it will have more "precommercial plus commercial thin" acres), we cannot make a complete analysis of the results. However, the allowable cut would increase by 3.8 million fbm/year on the Columbia and by 4.6 million fbm/year on the Alsea-Rickreall, indicating a considerable potential for the allowable cut to respond when the growth increase can be removed relatively quickly from the stands on which it occurs. Differences in the inventory do not appear to be very important.

Changing the Acreage Base

We tested the effect on the allowable cut of adding 1,000 acres of nonstocked land to the acreage base. This addition would be from converting 1,000 acres of hardwoods or brushland to conifer stands, if there were such acres outside the allowable-cut base.

The maximum per-acre impact that we could expect from an increase in the area base would be the sum of the proportion of acres in each management regime times the mean annual increment at culmination for that regime. Figure 4 shows these maximums to be 990 fbm/acre/year on the Columbia and 1,064 fbm/acre/year on the Alsea-Rickreall. Using the allowable cut model, the increases in allowable cut were 600 fbm/acre/year and 900 fbm/acre/year on the Columbia and Alsea-Rickreall, respectively. This again demonstrates that when increased growth must be held for considerable periods before it can be cut from the stands on which it occurs, the change in allowable cut will be less than the change in growth. Furthermore, the more inventory there is, the more responsive the allowable cut will be to growth changes.

Figure 4.--*Calculation of mean annual increment (MAI) per acre*

$$\left[\begin{array}{c}\text{Proportion}\\ \text{of acres}\\ \text{with genetics}\\ \text{only}\end{array}\right] \times \left[\begin{array}{c}\text{MAI}\\ \text{with}\\ \text{genetics}\end{array}\right] + \left[\begin{array}{c}\text{Proportion}\\ \text{of acres}\\ \text{with}\\ \text{thinning}\end{array}\right] \times \left[\begin{array}{c}\text{MAI}\\ \text{with}\\ \text{thinning}\end{array}\right] = \left[\begin{array}{c}\text{MAI/acre/year}\\ \text{for the}\\ \text{forest}\end{array}\right]$$

Columbia	(0.8) x (840) + (0.2) x (1,588) = 990 fbm/acre/year
Alsea-Rickreall	(0.7) x (840) + (0.3) x (1,588) = 1,064 fbm/acre/year

HOW INVENTORY AFFECTS THE ALLOWABLE CUT

Using the BLM management assumptions and base runs, we looked at the effect of the initial age-class distribution. We determined the allowable cut that would result if the initial inventory were fully regulated, i.e., each age class occupied $\frac{1}{\text{number of years in the rotation}}$ of the area (fig. 1). We compared that with the base run and with an accelerated harvest that dropped the initial inventory to the level of the fully regulated forest in the first decade. These comparisons indicate that at and above the inventory level of the fully regulated forest, an even distribution of age classes is more important than the level of inventory.

Table 3 shows that if the Alsea-Rickreall were fully regulated, the annual allowable cut would be only 0.4 million fbm (0.4 percent) less than the base run, even though the initial inventory was 37 percent less than in the base run. If the inventory is dropped to the fully regulated level by increased harvesting in decade one, however, the allowable cut is 4.5 million fbm (4.7 percent) less than the base run. This shows that the growth potential and the amount of inventory are not sufficient indicators of the ability of a forest to sustain a level of cut; the age-class distribution is also important.

For an additional comparison of the effect of inventory and age-class distribution, we "harvested" or "killed" by insect, disease, or fire 200 million fbm from the oldest age classes on each management unit by adjusting the initial inventory. We did this for the base run inventories and for the fully regulated inventories. The loss of 200 million fbm is a loss of 4-1/2 percent of the inventory on the Alsea-Rickreall and a loss of 6-1/2 percent on the Columbia for the base runs. For the fully regulated inventories, the loss of 200 million fbm is about 7 percent of the inventory in both cases. Table 4 shows that an inventory loss of a given amount reduces the allowable cut less when there is a larger inventory or a more evenly distributed inventory.

Table 3.--*Inventory and allowable cut for forest with annual growth potential of 93 million board feet*

Alsea-Rickreall	Inventory: Initial	Inventory: End of decade 1	Annual allowable cut
	Billion board feet	*Billion board feet*	*Million board feet*
Base run	4.3	--	96.2
Fully regulated	2.7	2.6	95.8
Accelerated harvest	4.3	2.6	91.7

Table 4.--*Annual allowable cuts with and without an inventory loss of 200 million board feet*

Master unit	Base run		Fully regulated	
	Base run inventory	Less 200 million board feet	Fully regulated inventory	Less 200 million board feet
	Million board feet			
Alsea-Rickreall (28 percent > 100 years)	96.2	96.1	95.8	95.3
Columbia (3 percent > 100 years)	94.9	92.6	97.4	97.0

Irregularities in the age-class distribution affect the allowable cut primarily through their effect on growth. When the highest sustainable even-flow cut is achieved, the cutting age tends toward the age of culmination of mean annual increment. When there are irregularities in the age-class distribution, some stands will be held beyond the age of culmination, and/or some stands will be cut earlier than the age of culmination. In either case, total growth is reduced and the allowable cut is affected accordingly.

CONCLUSIONS

These analyses provide a basis for estimating the effect on the allowable cut of changes in the extent or growth response of growth-stimulating treatments, changes in the acreage base, and changes in the extent or age-class distribution of the inventory.

These analyses show that allowable cut responds more to changes in long-term growth:

(1) Where there is a high initial inventory that can support a level of harvest above the growth in merchantable stands for a long period during which growth is building up.

(2) Where the age classes are well distributed so that the imbalances brought about by the change in assumed growth do not create more extreme imbalances. The possibility exists that an imbalance would complement rather than amplify existing imbalances, but this would not appear to be the usual case.

(3) Where growth increases can be cut sooner from the stands on which they occur, thus reducing the need to accelerate the rate of harvest from other stands.

(4) Where growth increases are not too large. At some level, the change in allowable cut is proportional to the change in growth. However, as growth increases are added, a point will be reached where the imbalance imposed becomes constraining and the increase in allowable cut becomes smaller with each successive increment of growth.

These analyses show that the

allowable cut responds more to changes in the initial inventory or short-term growth:

(1) Where the initial inventory is already low and the inventory is being fully utilized to counterbalance the existing imbalance in cut and growth.

(2) Where the initial inventory is not well distributed and the inventory is being fully utilized to counterbalance the existing imbalance in the age-class distribution.

These conclusions provide a basis for quantitative estimates of the effect of various changes in assumptions in calculating even-flow allowable cuts. However, an even-flow allowable cut model can be viewed as one end of a continuum of models with constraints on the relation of the level of harvest between time periods. These conclusions can therefore be expected to apply qualitatively to models with less restrictive periodic flow constraints.

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AUTOMATED ANALYSIS OF TIMBER ACCESS ROAD ALTERNATIVES

Doyle Burke

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Pacific Northwest Forest and Range Experimental Station
U.S. Department of Agriculture Forest Service Portland, Oregon

ABSTRACT

The evaluation of timber access road alternatives is one of the primary tasks in timber harvest planning and design. During the planning stages, it is also one of the most difficult to accomplish quantitatively because a basis for comparison is related to such values as grade, length, horizontal and vertical curvature, and volumes of excavation and embankment. Within reasonable time constraints, these values are almost impossible to produce with any accuracy. Evaluating several alternatives is usually out of the question.

The analysis of timber access road alternatives involves four analytic procedures:

1. Road projection of a proposed road corridor with a specified grade across a topographic or orthophoto map,
2. horizontal alinement analysis of the projected road grade,
3. vertical alinement analysis of the horizontal alinement, and
4. computation of excavation and embankment quantities.

Automated analysis of these procedures has been implemented on a desk-top calculator system using digitizer and plotter peripherals. The logic and mathematics are discussed.

The analytic system presented is designed for preharvest planning and is based on map data. The analytic routines are structured to accept field data with minor programing changes.

Keywords: Road administration/planning (forest), computer programs, timber management planning.

INTRODUCTION

Timber harvest planning and design always begins with a thorough analysis of the maps and aerial photographs covering the proposed harvest area. This aspect of the design process can, if properly done, reveal much about the planning area and increase the efficiency of the layout crews in the field. Alternative roads, landings, and settings can be evaluated on paper, and the most suitable combination of these scheduled for field examination.

Much information about the timber stand and the terrain it occupies may be determined from maps and photographs. Quantitative values for area, volume, species, size, and distribution can be obtained by the experienced planner. Simple methods and procedures for doing this are readily available to the forest manager.

The quantitative evaluation of road and landing alternatives is much more complex. Bases for comparison are such values as grade, length, horizontal and vertical alinement, and volumes of excavation and embankment. These values are not readily apparent from the topographic maps but could be laboriously obtained manually if time allowed. Even so, examining several alternatives is usually out of the question.

This paper presents an analytic system for evaluating timber access road alternatives, using topographic maps and a desk-top calculator, digitizer, and plotter. The procedure is simple, fast, accurate, and allows maximum interaction and engineering judgment on the part of the designer. This information should be useful to resource managers and of particular interest in planning logging and transportation systems.

THE DESIGN PROCESS

The general design process for timber access roads can produce results useful in evaluating and comparing planning alternatives. The design flow of this process is illustrated in figure 1.

Each step of the design process produces results that are used to 1) determine if that alternative is satisfactory with respect to design standards, and 2) generate an array of information to be used in comparing alternate routes. The results obtained at the various steps of the design process are shown in figure 2.

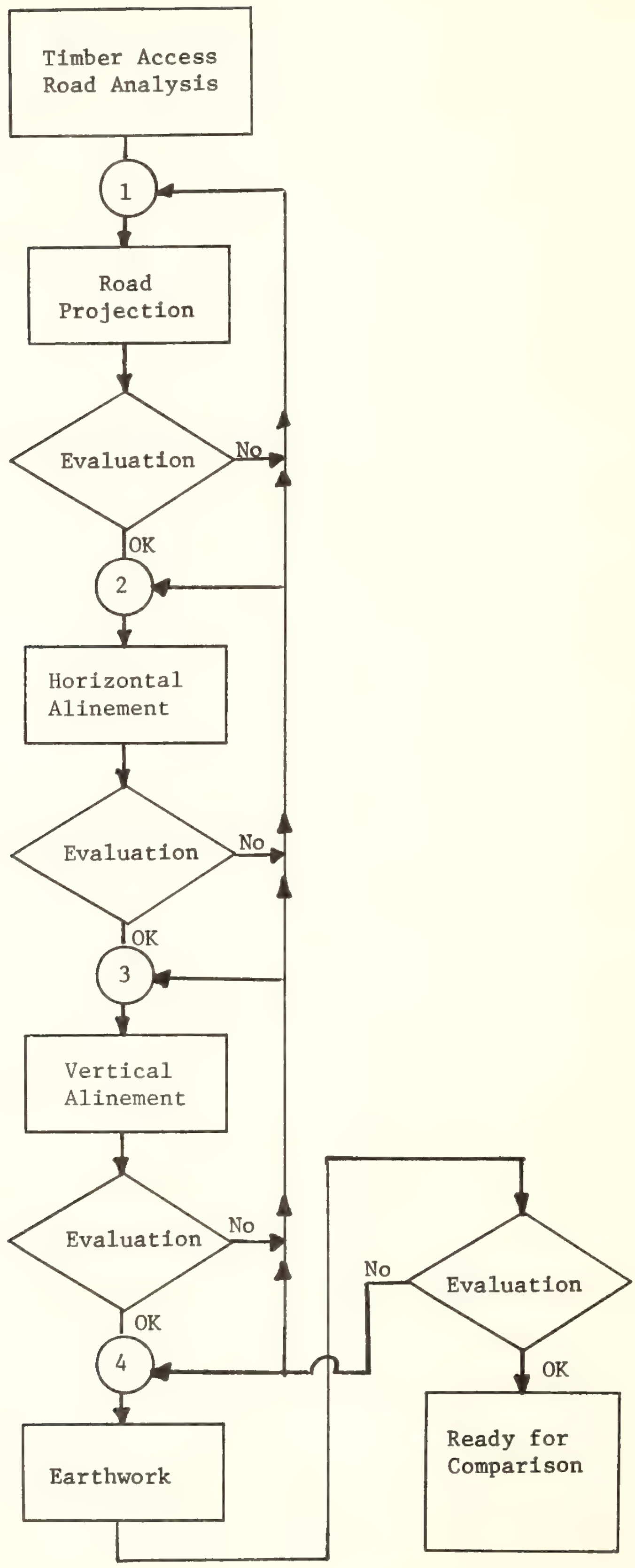


Figure 1.--Design flow for timber access road analysis.

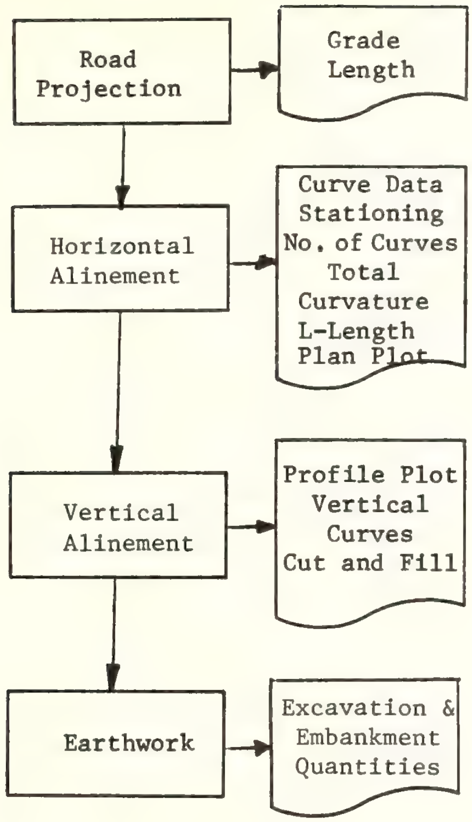


Figure 2.--Design results useful in evaluating timber access road alternatives.

THE DESIGN SYSTEM

A design system capable of high-speed data manipulation, maximum designer interaction, and ready availability is needed to facilitate rapid and accurate evaluation of timber access road alternatives. Desk-top calculator systems with digitizer and plotter facilities best meet these requirements.

Modern desk-top calculator systems (fig. 3) are capable of high-speed, complex numeric computations with data input and output through digitizers, plotters, and printers. Maximum designer interaction is possible because the designer brings his maps, photographs, and concept of the problem directly to the system and uses his skill, knowledge, and judgment to analyze the trial road, vary its parameters, and converge on an acceptable solution. The desk-top computer system relieves the designer of routine "number crunching" and allows him to apply professional level skills and judgment to the problem. This design system allows the designer to immediately see the results of his decisions, make desired changes, and carry out many more design cycles than are possible using manual methods or even some methods employing large-scale computer systems.

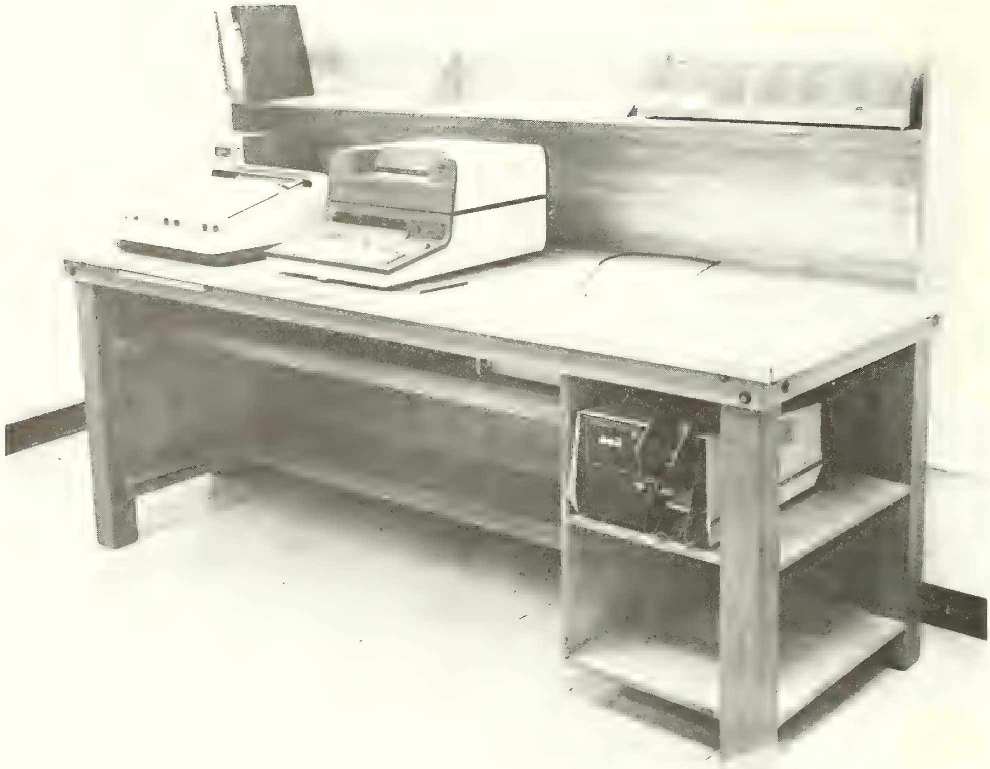


Figure 3.--Desk-top calculator system with digitizer, plotter, printer, and card reader.

The use of the digitizer in this design process is indispensable. The digitizer is necessary to convert the graphically displayed information on the topographic map to numeric coordinates (X, Y, Z). These coordinates are transferred to the computer and processed by the analytic routines. The results are then displayed on the plotter and printer for evaluation by the designer.

DESCRIPTION OF ANALYTIC ROUTINES

Road Projection

The road projection routine is used by the designer to project trial roads at selected grades from a topographic or orthophoto map base. The map is placed on the digitizer and trial locations projected using the digitizer cursor. Information from the digitizer is processed by the desk-top calculator, and an overlay plot of the routes is made on the plotter. The plots from this routine will subsequently be used by the horizontal alinement routine. The general logic for this routine is shown in figure 4.

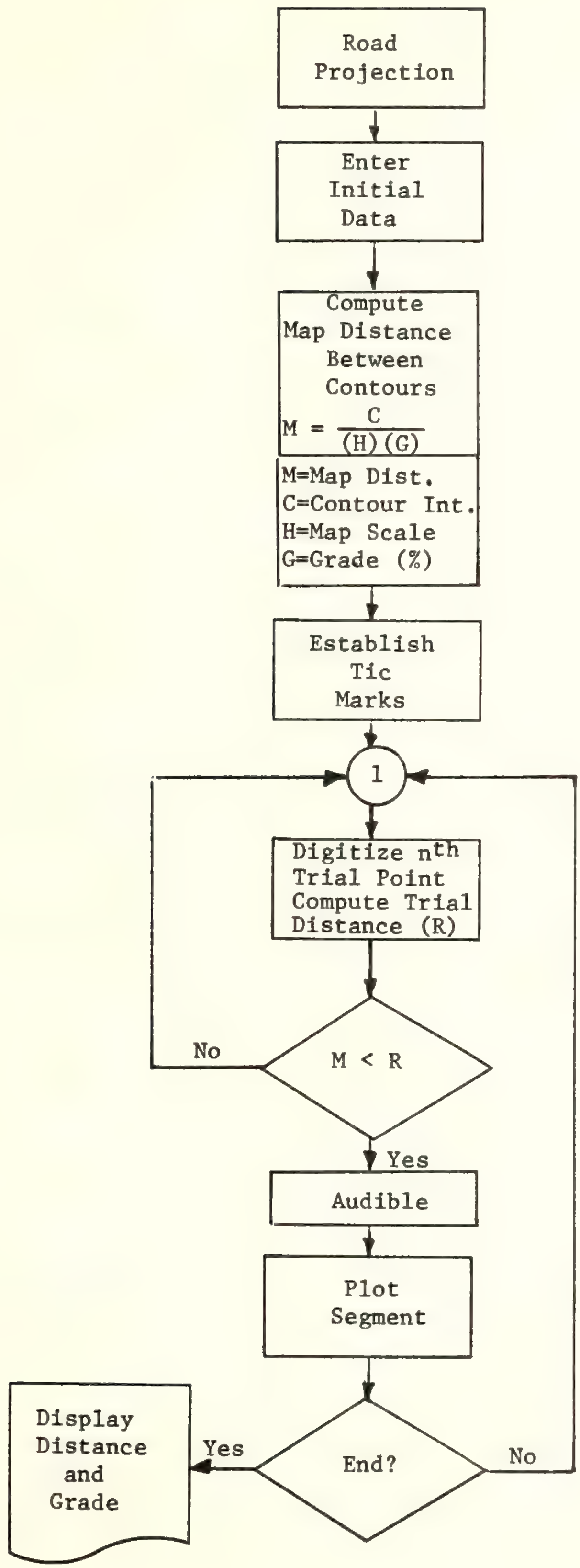


Figure 4.--Macroflow chart for road projection routine.

Horizontal Alinement

This routine is used to develop the horizontal alinement data using the trial grade lines produced by the road projection routine. The plotted grade lines on the overlay are transferred to the map positioned on the digitizer. Using the map and the grade line overlay, P.I. points (point of intersection between tangents) are selected using the digitizer. This information is processed by the calculator, L-line data printed (curve data for each curve, stationing, number of curves, and total curvature) and plan view of the L-line plotted. The plots from this routine will be used by the vertical alinement routine. The general logic for the horizontal alinement routine is shown in figure 5.

The calculations for L-line stationing and curve data are similar to those used in standard highway engineering texts.[1/]

Vertical Alinement

The vertical alinement routine is used to introduce vertical curve geometry to the road grade and produce cut and fill depths at the centerline of the road. A labeled plot of the road ground profile and grade profile is also produced.

The overlay generated by the horizontal alinement routine is used to determine ground elevations from the topographic base map on the digitizer. The mathematics for the vertical curve geometry used by the vertical alinement routine are similar to those used in standard highway engineering texts (e.g., see footnote 1).

The general logic for the vertical alinement routine is shown in figure 6.

Earthwork Routine

The earthwork routine combines cut and fill information from the vertical alinement routine with descriptions of the road template (road bed width, cut and fill slopes, and ground slopes) to produce excavation and embankment quantities. The macroflow chart for this routine is shown in figure 7.

The computations for roadway cross-section areas used in the earthwork routine are based on "slope stake" notation. This decision allows the routine to accept data from the digitizer, or in field note form with minor program changes. To accept data from the digitizer, slope stake points are located using slope intercept calculations.

1/ *Thomas F. Hickerson. Route surveys and design. 4th edition, McGraw-Hill Book Co., Inc., New York, 1959.*

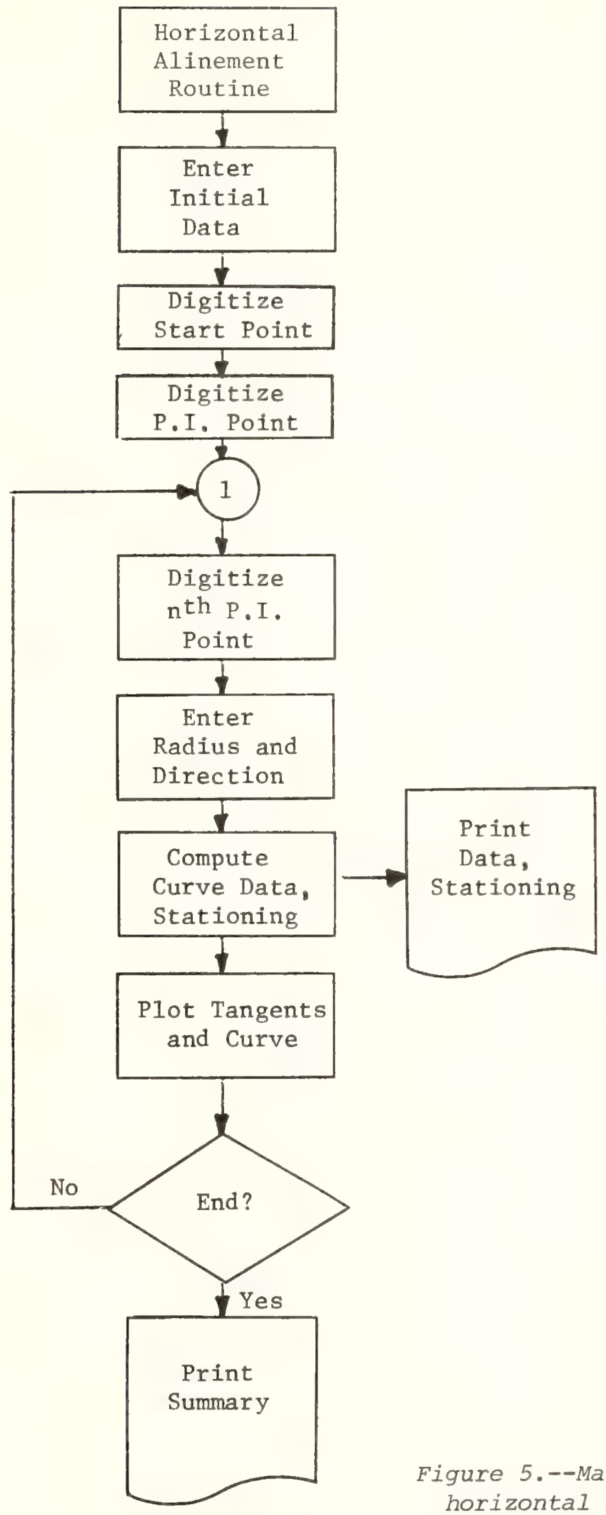


Figure 5.--Macroflow chart for horizontal alinement routine.

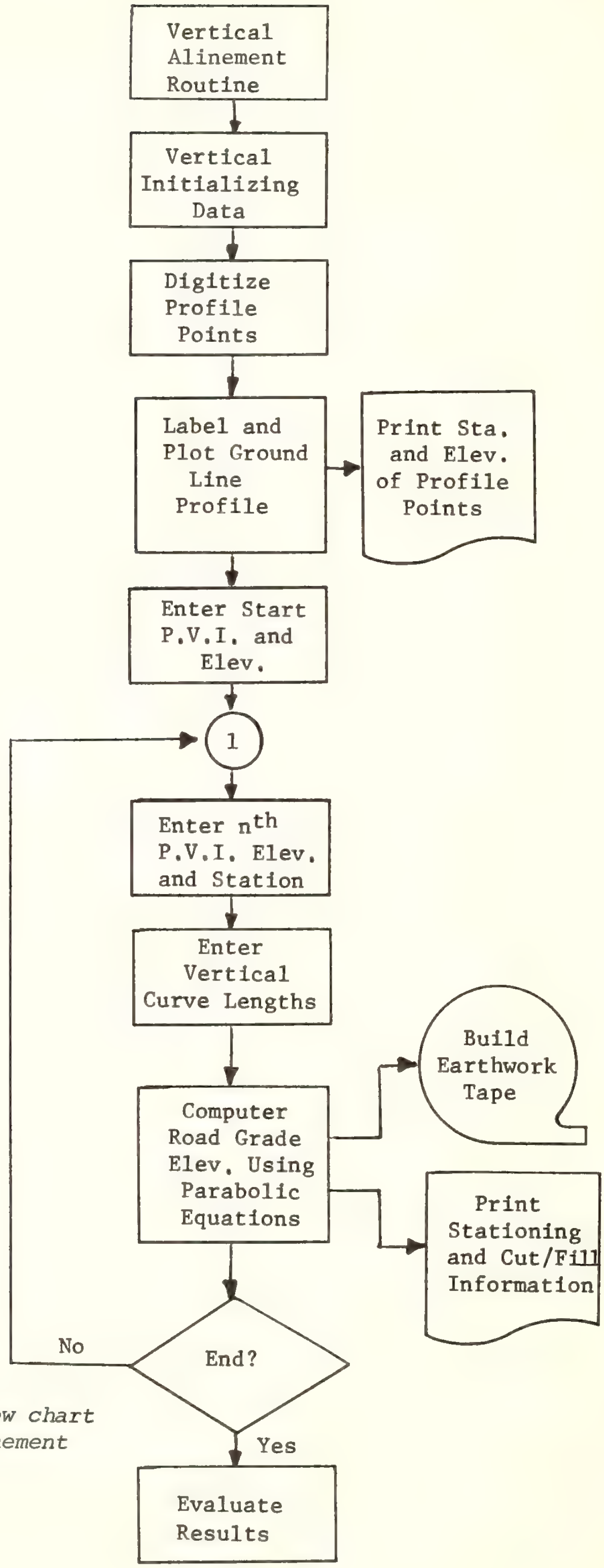


Figure 6.--Macroflow chart for vertical alinement routine.

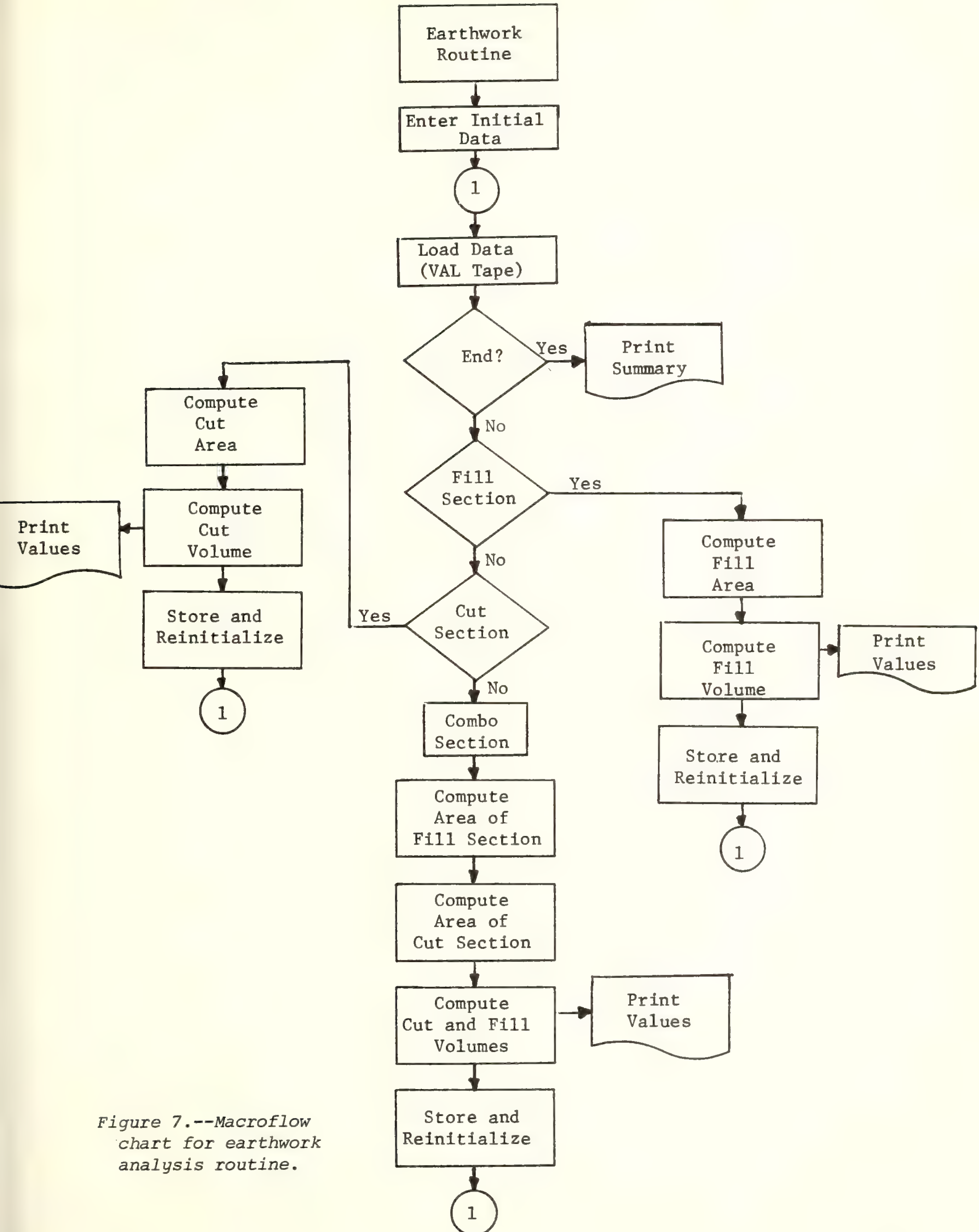


Figure 7.--Macroflow chart for earthwork analysis routine.

Excavation section (refer to fig. 8). --

$$\frac{H1 - C2}{S} = \frac{H1}{C} + R/2$$

$$H1 - C2 = \frac{H1(S)}{C} + R/2\ (S)$$

$$H1(C) - H1(S) = C2(C) + R/2\ (S)(C)$$

$$H1 = \frac{C2(C) + R/2(S)(C)}{C - S}$$

and, using the same geometry,

$$C2 - H2 = \frac{S(H2)}{C} + R/2\ (S)$$

$$C(C2) - C(H2) = S\ (H2) + R/2\ (C)(S)$$

$$H2 = \frac{C2(C) - R/2\ (C)(S)}{C + S}$$

and

$$X4 = \frac{H1 - C2}{S}$$

$$D2 = X4 + R/2$$

$$D2 = \frac{H1 - C2}{S} + R/2$$

$$X5 = \frac{H2}{C} + R/2$$

$$D1 = X5 + R/2$$

$$D1 = \frac{H2}{C} + R$$

Area of Excavation Section $= X = 0.5[(H1)(D1) + (H2)(D2)]$

Embankment section (refer to fig. 9). --

Using the same geometry,

$$H1 = [(C1)(F) + R/2\ (S)(F)] \ /\ (F-S)$$

$$H2 = [(C1)(F) - R/2\ (S)(F)] \ /\ (F+S)$$

$$D1 = (H2/F) + R$$

$$D2 = [(H1 - C1)\ /\ S] + R/2$$

Area of Embankment Section $= 0.5\ [H1(D1) + H2(D2)]$

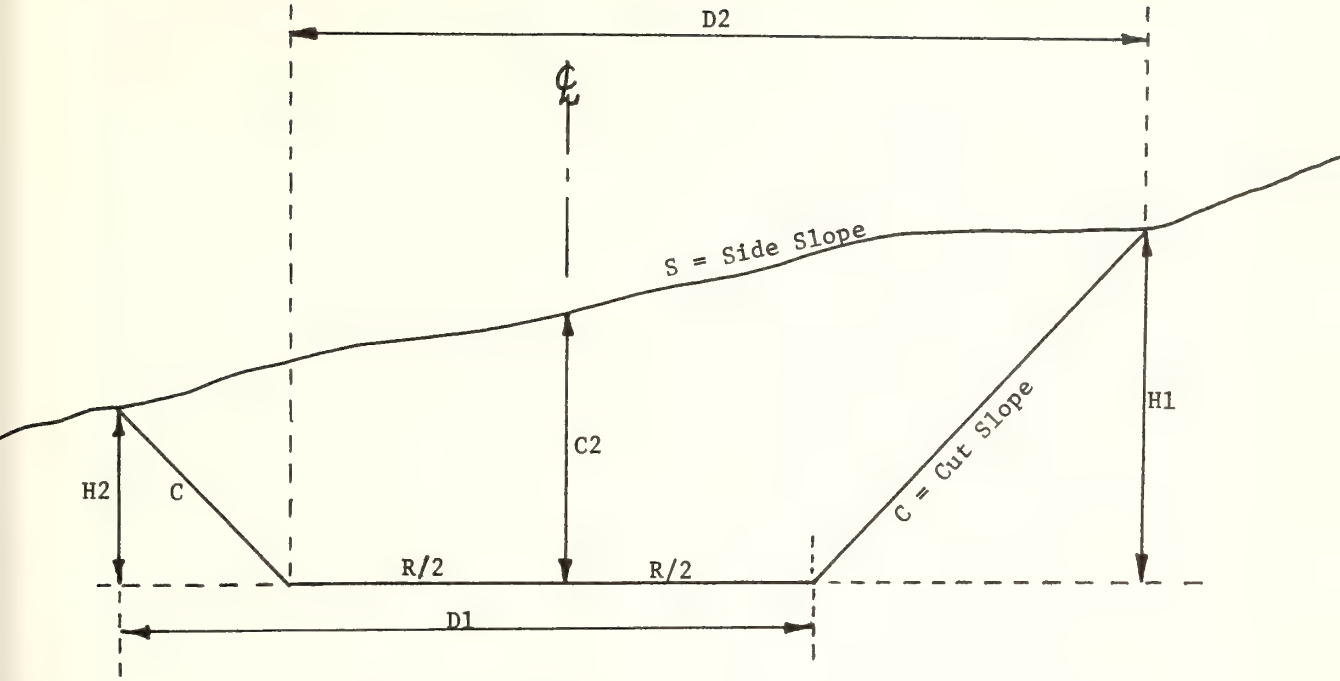


Figure 8.--Finding area of excavation section.

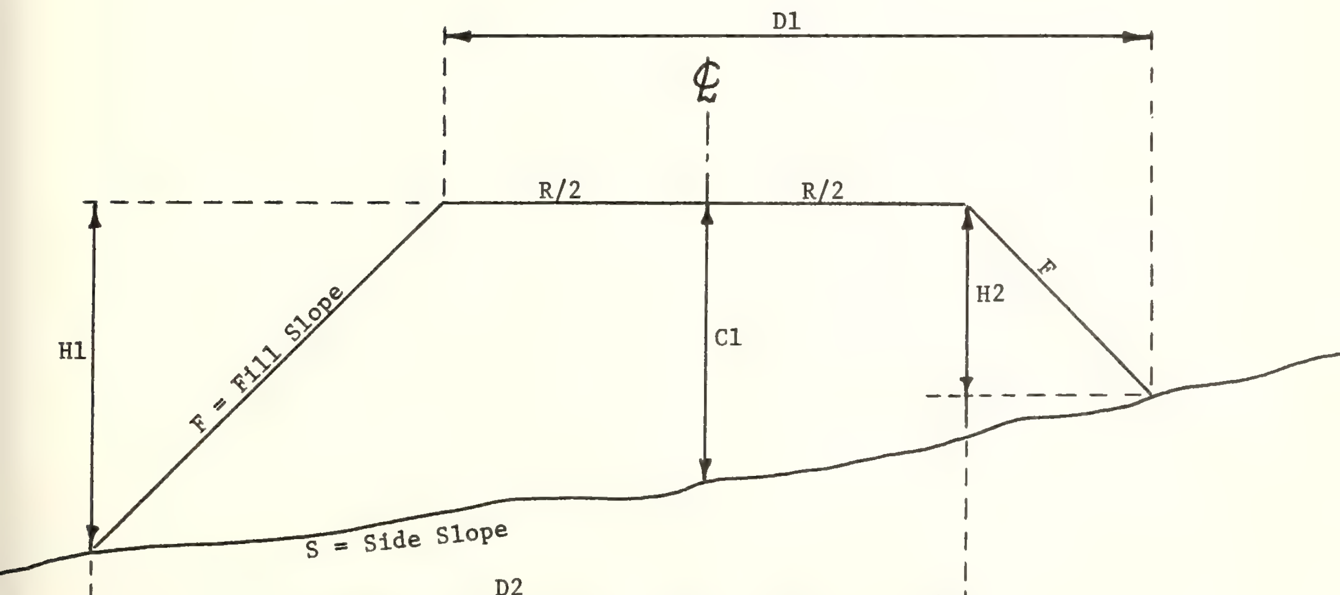


Figure 9.--Finding area of embankment section.

Combination section.--In a combination section (one with excavation and embankment) there are two conditions to be treated: (a) fill at centerline, and (b) cut at centerline.

1. Fill at centerline (refer to fig. 10)

$$D3 = \frac{C1}{S}$$

$$D1 = \frac{H1}{S}$$

$$D1 = \frac{H1}{C} + (R/2 - D3)$$

$$\frac{H1}{S} = \frac{H1}{C} + (R/2 - D3)$$

$$H1 = \frac{H1(S)}{C} + S(R/2 - D3)$$

$$H1(C) = H1(S) + (R/2 - D3)(S)(C)$$

$$H1(C-S) = (R/2 - D3)(C)(S)$$

$$H1 = \frac{(R/2 - D3)(S)(C)}{(C - S)}$$

Area of excavation = $[H1\ (R/2 - D3)]\ /\ 2$

then,

$$D2(S) = D2(F) - (R/2 + D3)(F)$$

$$D2(S) - D2(F) = -\ (R/2 + D3)(F)$$

$$D2 = \frac{(R/2 + D3)(F)}{F - S}$$

and

$$H2 = D2(S)$$

$$H2 = \frac{(R/2 + D3)(F)(S)}{F - S}$$

Area of embankment = $M = [(R/2 + D3)\ H2]\ /\ 2$

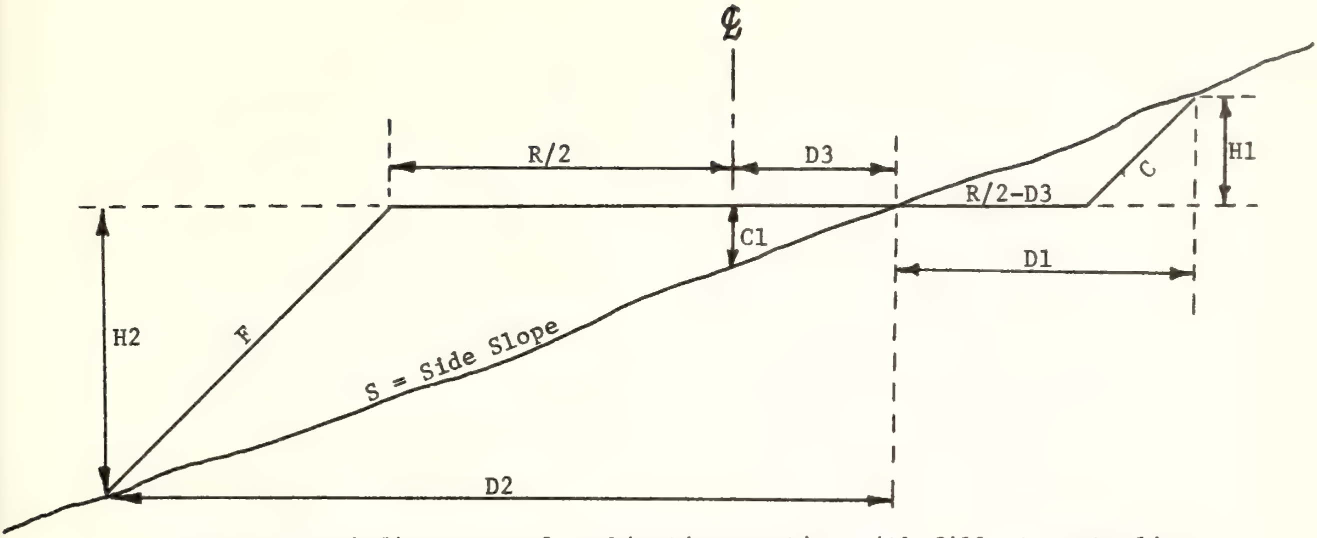


Figure 10.--Finding area of combination section with fill at centerline.

2. Cut at centerline (refer to fig. 11)

Using the same geometry as in fill,

$$D3 = \frac{C2}{S}$$

$$D1 = \frac{H1}{C} + (R/2 + D3)$$

$$D2 = H2/S$$

$$H1 = \frac{(R/2 + D3)(S)(C)}{C - S}$$

Area of excavation = $[H1\ (R/2 + D3)]\ /\ 2$

$$H2 = \frac{(R/2 - D3)(F)(S)}{F - S}$$

Area of embankment = $[(R/2 - D3)\ H2]\ /\ 2$

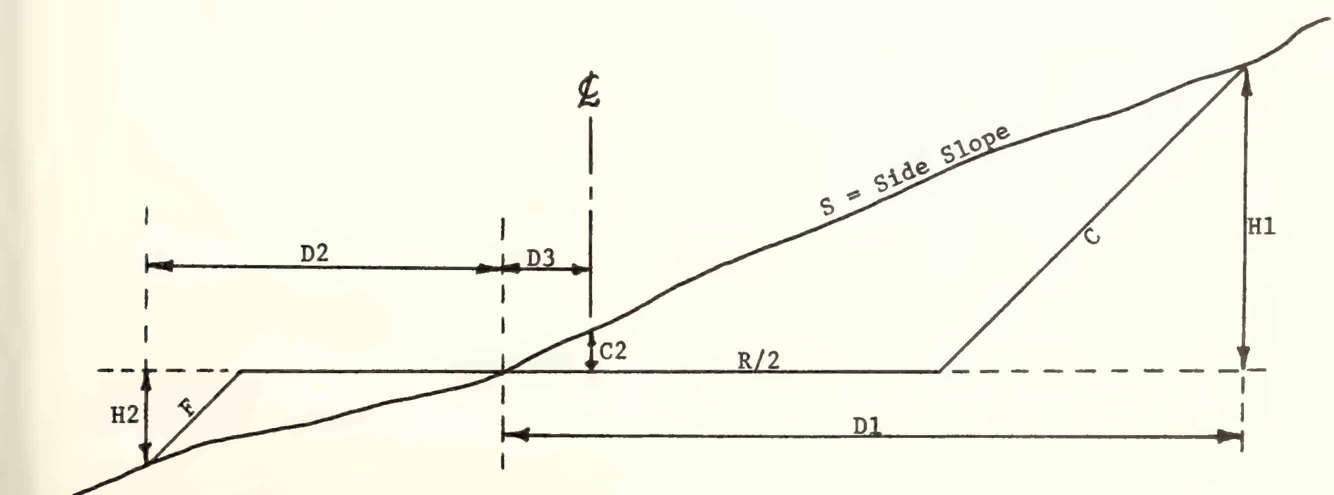


Figure 11.--Finding area of combination section with cut at centerline.

LIMITATIONS

The design system routines discussed in previous sections will treat the specific problem of evaluating timber access road alternatives. Although the program codes are designed for relative ease of modification and use, there are several limitations that should be discussed.

First, the analytic routines are specifically designed to produce quantitative information for evaluating planning alternatives. In this respect, topographic data are expected to come from topographic or orthophoto maps. The routines may, however, be modified to accept field data by altering the program input statements.

Second, the horizontal alinement routine uses curve radius rather than degrees. It is felt that curvature is easier to visualize on maps using radii. The analytic routine provides for the degree function and could accept degree input.

Third, the roadway template does not provide for ditches, curve widening, superelevation, or curvature corrections for earthwork. For planning purposes, it is felt that these items make a relatively small contribution to volumes, while detailed road design will require their consideration. Adjustments for shrink or swell can be made from the earthwork summary.

The design of the analytic routines is general enough that the above limitations can be eliminated without major logic or programing changes. What changes are required can be accomplished by any competent BASIC language programer.

APPENDIX A

EXAMPLE PROBLEM OPERATING INSTRUCTIONS

Explanation

The purpose of this example is to illustrate the procedure for locating a road on a topographic map and then evaluating the proposed location in terms of horizontal alinement, vertical alinement, and earthwork. The operating instructions presume a knowledge of the Hewlett-Packard Model 9830A[2/] system configuration (fig. 12) and initializing procedures. Supplementary display instructions are provided under program control.

1. Install "Timber Access Road Pac" tape in the calculator. Place "Timber Access Road Pac" overlay (fig. 13) over S. F. keys.
2. Press LOAD, EXECUTE.
3. Press RUN, EXECUTE.
4. Select the desired program by pressing the appropriate S. F. key. Keep in mind that the earthwork program post-processes vertical alinement program data.
5. Refer to program instructions for program selected.
6. General instructions may be obtained by pressing S. F. key 4.

Road Projection

1. Press S. F. key Ø.
2. Place the map on the digitizer (fig. 14).
3. Place transparent overlay material on the plotter. Adjust plotting area for 9 x 14 inches.
4. Enter map scale, feet per inch.
5. Enter contour interval, feet.
6. Digitize first tic mark (used to aline overlay on the map) after hearing beep. Press [S] on the cursor.
7. Digitize second tic mark. Press [S] on the cursor.
8. Enter trial grade, percent.
9. Digitize road starting point. Press [S] on the cursor.
10. Digitize the road location by moving the cursor to the next contour away from the starting point, press [C] on the cursor, and move the cursor along the contour until a beep is heard. Move the digitizer to the next contour and continue across the map along the desired road location. To change grade, press STOP, CONT 250, EXECUTE, and repeat instructions beginning at step 8. The plotter will plot the location on the overlay.
11. At the end of the road location, press STOP, SHIFT, and S. F. key Ø.
12. The printer will print summary of input data and length of the road projection in feet and miles.
13. Follow display instructions for new trial road.

[2/] *The use of trade, firm, or corporation names in this publication is not an official endorsement or approval by the U.S. Department of Agriculture of any product to the exclusion of others which may be suitable.*

Figure 12.

MODEL 9830A SYSTEM CONFIGURATION

MODEL 30 CALCULATOR

☐ 1760 Words RWM, Basic Calculator
☒ 3808 Words RWM, Option 275
☐ 7904 Words RWM, Option 276

ROMS

Plotter Control	271	
String Variables	274	
Extended I/O	272	

PERIPHERALS	SELECT CODE
☐ 98 A Card Reader	
☐ 9861A Typewriter	
☒ 9862A Plotter	Primary
☐ 9863A Paper Tape Reader	
☒ 9864A Digitizer	Primary
☒ 9865A Cassette Memory	5
☒ 9866A Thermal Page Printer	Primary
☐ 9867 Mass Memory Drive (Unit No.)	
☐	
☐	
☐	
☐	
☐	

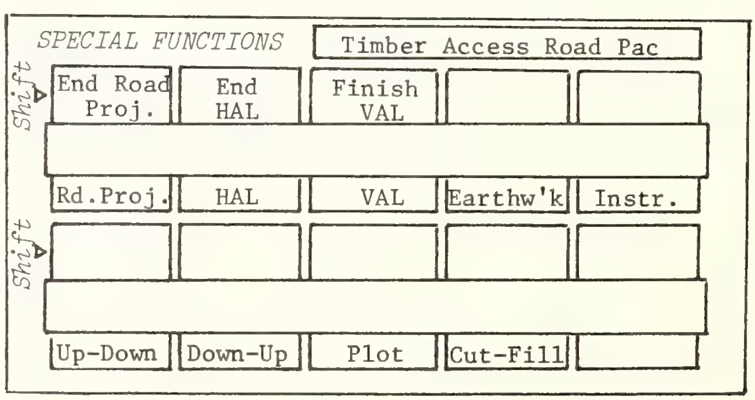


Figure 13.--Special function key overlay card.

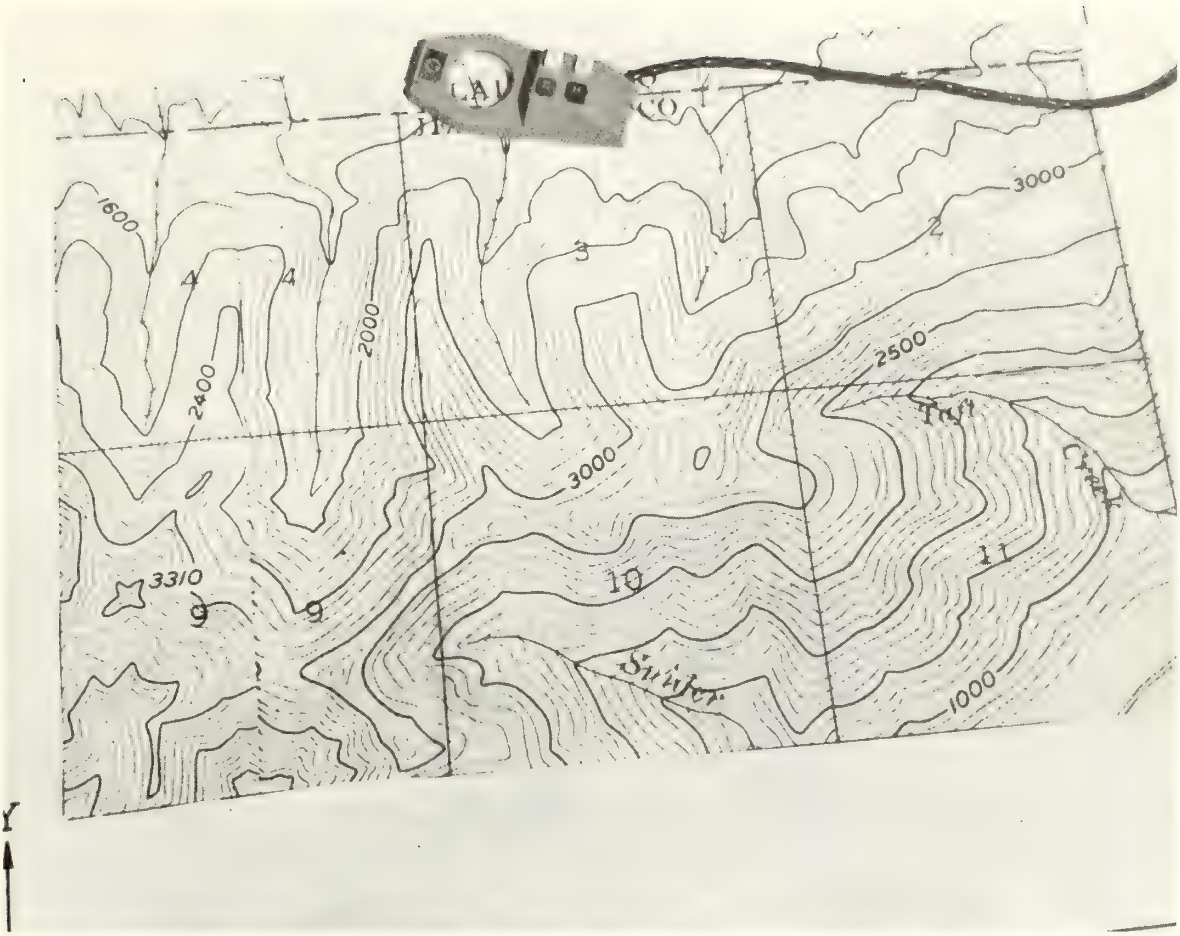


Figure 14.--Map positioned on the digitizer.

Horizontal Alinement

1. Press S.F. key 1.
2. Place road projection plot on the map (fig. 15).
3. Place transparent overlay material on the plotter. Use 9- x 14-inch plotting area.
4. Enter map scale, feet per inch.
5. Plotter will label plot.
6. Digitize starting point of the road. Use topographic map and overlay plot to select point. Press [S] on the cursor.
7. Digitize the next P.I. point. Use the map and overlay plot to select the appropriate point. Press [S] on the cursor. The plotter will plot the tangent.
8. Digitize the next P.I. point.
9. Enter curve radius, feet.
10. Enter direction, right or left.

11. The plotter will identify curve and plot curve. Printer will list the curve data:

- Delta
- Radius
- Tangent
- Length
- P. C. station
- P. T. station
- P. I. equation

12. Repeat at step 8, for remaining road length.
13. At the end of the road, press STOP, SHIFT, S. F. key 1. The printer will list a summary giving total number of curves, total curvature, and L-line distance in feet and miles.

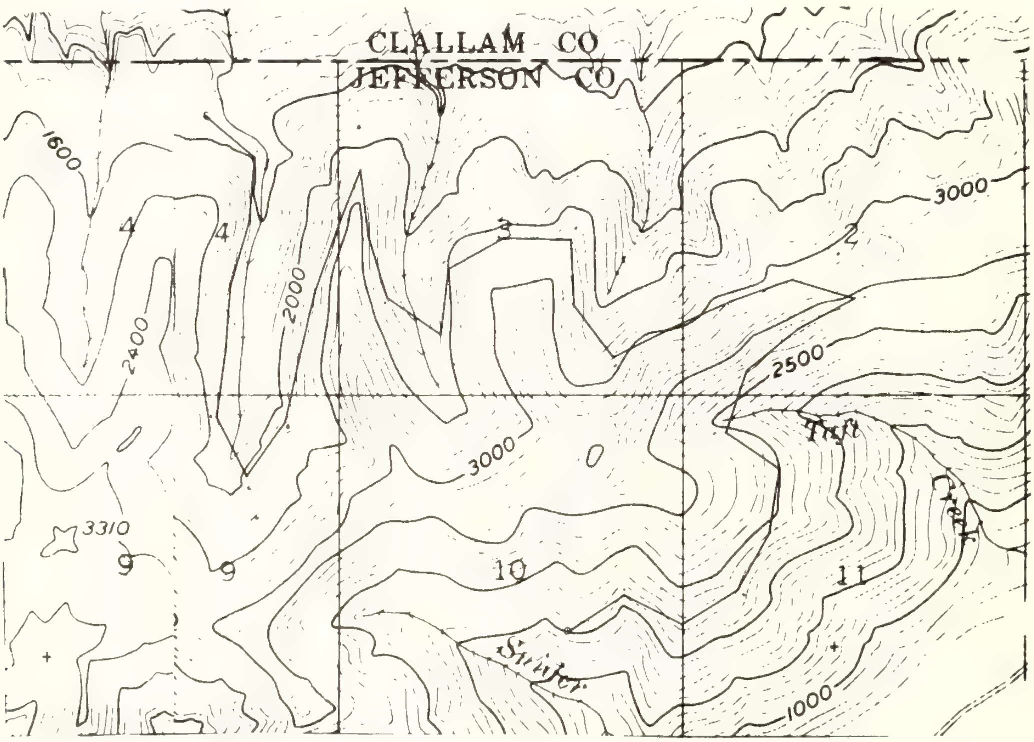


Figure 15.--Road projection plot positioned on the map.

Vertical Alinement

1. Place horizontal alinement plot on the topographic map (fig. 16).
2. Place cross-section paper on the plotter. Use 9- x 14-inch plotting area and install tape cassette in cassette memory device premarked with appropriate number of 20-word files.
3. Enter map scale, feet per inch.
4. Enter contour interval, feet.
5. Enter starting elevation of road, feet.

6. Digitize road profile. Digitize each point where a contour crosses the L-line on the overlay, using [S] on the cursor. Begin at station 0+00 and use the S.F. keys 5 and 6 to change ascending to descending points, and vice versa. The program assumes ascending points to start.

7. When profile is digitized, press STOP, S.F. key 7.

8. Enter desired horizontal and vertical scale of the plot; feet, feet.

9. The plotter will label the plot and plot output. The printer will list distance and elevation.

10. For analysis of cut or fill at the centerline, press S.F. key 8. This provides a routine to allow the introduction of parabolic vertical curves.

11. Enter grade elevation at station 0; feet, 0, EXECUTE.

12. Enter first P.V.I. (point of vertical intersection) elevation and station; feet, feet, EXECUTE.

13. Enter next P.V.I. elevation and station; feet, feet, EXECUTE.

14. Enter vertical curve length in stations; e.g., 600 feet = 6 stations. Plotter will plot road grade and the printer will list cut and fill data. The data will be stored on tape.

15. Repeat at step 13 until the end of the road is encountered.

16. Press SHIFT, S.F. key 2.

17. The plotter will complete the plot (fig. 17), and the printer will complete the listing and print a summary of vertical curve data.

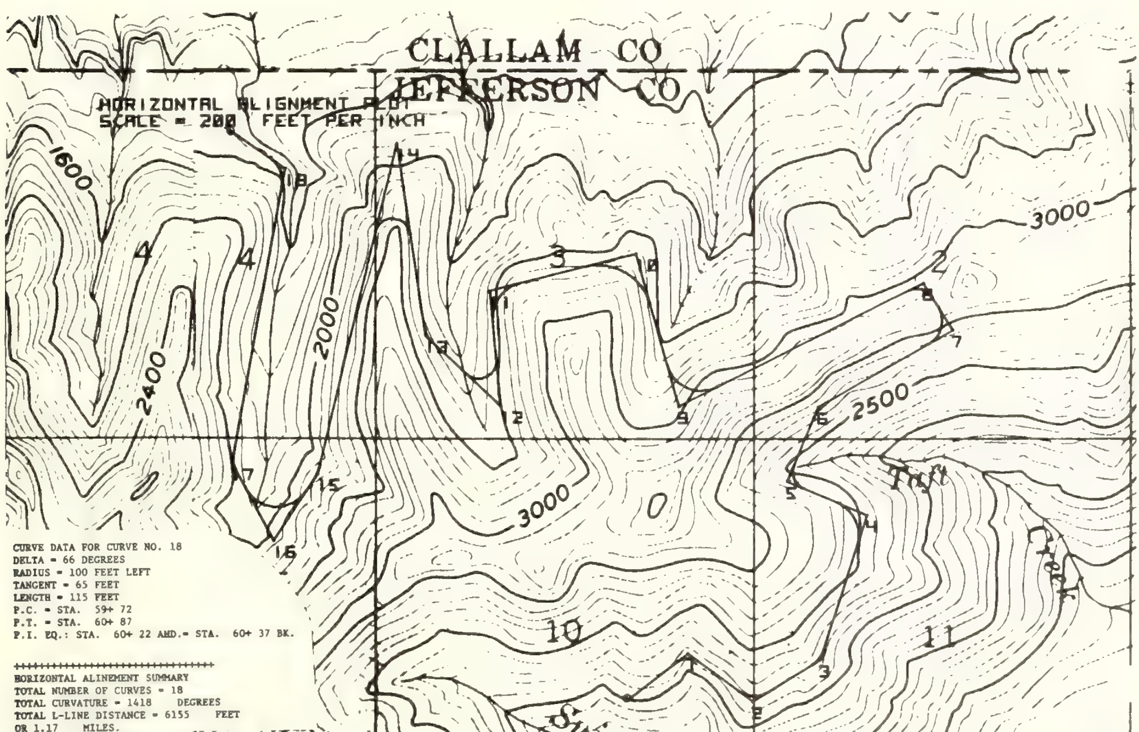
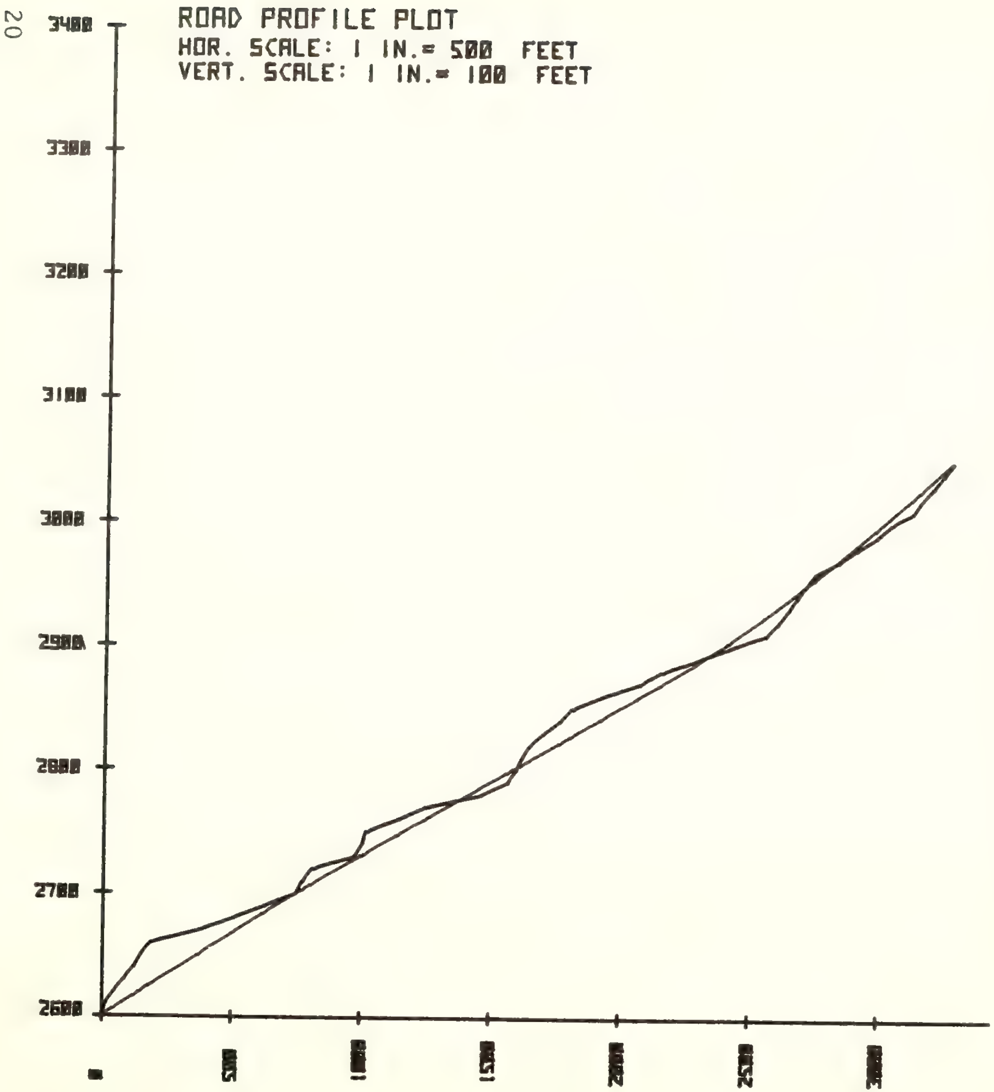


Figure 16.--Horizontal alinement plot positioned on map with partial printer listing.



VERTICAL CURVE DATA

STATION		GROUND	GRADE	CUT	FILL
0		2600.0	2600.0	0	0
0.0	+ 10.8	2610.0	2601.4	8.6	
0.0	+ 44.8	2620.0	[illegible]	14.0	
0.0	+ 82.3	2630.0	[illegible]	19.0	
1.0	+ 22.3	2640.0	2616.7	23.7	
1.0	+ 48.0	2650.0	2619.7	30.3	
1.0	+ 87.7	2660.0	2625.0	35.0	
3.0	+ 75.7	2670.0	2650.1	19.9	
5.0	+ 7.3	2680.0	2667.6	12.4	
6.0	+ 27.3	2690.0	2683.6	6.4	
7.0	+ 48.9	2700.0	2699.4	0.6	
7.0	+ 73.3	2710.0	2702.4	7.6	
8.0	+ 11.7	2720.0	2707.2	12.8	
9.0	+ 74.9	2730.0	2727.0	3.0	
10.0	+ 4.6	2740.0	2730.6	9.4	
10.0	+ 17.4	2750.0	[illegible]	17.9	
11.0	+ 43.7	2760.0	2747.2	12.5	
12.0	+ 47.4	2770.0	2759.7	10.3	
14.0	+ 62.3	2780.0	2783.5		3.5
15.0	+ 64.3	2790.0	2797.7		7.7
15.0	+ 97.1	2800.0	2801.7		1.7
16.0	+ 18.4	2810.0	2804.2	5.8	
16.0	+ 48.1	2820.0	2807.8	12.2	
17.0	+ 0.6	2830.0	2814.2	15.8	
17.0	+ 66.6	2840.0	2822.1	17.9	
18.0	+ 11.1	2850.0	2827.5	22.5	
19.0	+ 29.1	2860.0	2841.7	18.3	
20.0	+ 76.5	2870.0	2858.7	11.3	
21.0	+ 55.8	2880.0	2869.1	10.9	
22.0	+ 95.8	2890.0	2886.7	3.3	
24.0	+ 13.5	2900.0	2903.6		3.6
25.0	+ 59.2	2910.0	2924.3		14.3
26.0	+ 7.6	2920.0	2931.8		11.8
26.0	+ 46.4	2930.0	2936.0		6.0
26.0	+ 78.0	2940.0	2943.2		3.2
27.0	+ 15.2	2950.0	2949.3	0.7	
27.0	+ 50.8	2960.0	2955.1	4.9	
28.0	+ 36.7	2970.0	2969.7	0.3	
29.0	+ 13.7	2980.0	2982.4		2.4
29.0	+ 90.0	2990.0	2995.7		5.7
30.0	+ 43.8	3000.0	3005.3		5.3
31.0	+ 30.1	3010.0	3021.0		11.0
31.0	+ 62.6	3020.0	3027.0		7.0
32.0	+ 8.0	3030.0	3035.5		5.5
32.0	+ 47.7	3040.0	3043.0		3.0
32.0	+ 84.5	3050.0	3050.0		0.0

STATION	P.V.I. ELEV.	V.C. LENGTH
750.0	2700.0	3.0
1600.0	2902.0	4.0
2420.0	3901.0	5.0
3050.0	3004.0	6.0

Figure 17.--Completed road profile plot with partial printer listing.

Earthwork

1. Press S. F. key 3.
2. Rewind data tape on cassette memory.
3. Enter road bed width, feet, EXECUTE.
4. Enter cut slope, value, EXECUTE: 1 (1 = 1:1).
5. Enter fill slope, value, EXECUTE: 1 (1.5 = 1.5:1).
6. Enter number of side slope breaks to be used (maximum of 20), value, EXECUTE.
7. Enter each side slope and ending station, side slope, ending station, EXECUTE. Enter side slope as a decimal (e.g., 25 percent = 0.25).
8. The printer will list results of earthwork analysis and summary of excavation and embankment (fig. 18).

```
ROADBED WIDTH = 16.0     FEET
CUT SLOPE RATIO = 1.0   :1
FILL SLOPE RATIO = 1.5   :1
SIDE SLOPE OF 45.0     PERCENT ENDS AT STA. 1500.0
SIDE SLOPE OF 30.0     PERCENT ENDS AT STA. 2200.0
SIDE SLOPE OF 50.0     PERCENT ENDS AT STA. 4300.0
```

EARTHWORK QUANTITIES

	CENTER-LINE		AREA (SQ.FT.)		VOLUME (CU.YD)	
STATION	CUT	FILL	EXC	EMB	EXC	EMB
0.0	0.0	0.0	26.2	26.2	0.0	0.0
312.0	0.0	11.2	0.0	295.9	151.3	1060.9
446.2	0.0	4.6	0.0	110.0	0.0	1008.5
591.6	0.8	0.0	39.8	24.8	107.3	363.0
780.4	2.0	0.0	62.5	18.4	357.6	151.0
985.9	2.2	0.0	68.7	16.1	498.9	131.5
1216.5	2.5	0.0	73.9	14.1	609.0	128.9
1432.4	4.9	0.0	197.2	0.0	1084.4	56.2
1699.5	3.3	0.0	130.6	0.0	1661.4	0.0
1977.0	0.8	0.0	23.9	12.3	835.1	63.2
2233.0	0.1	0.0	33.2	32.0	273.6	209.9
2450.8	2.8	0.0	92.5	16.2	510.4	194.2
2711.0	2.3	0.0	78.3	21.7	825.8	182.6
2975.9	1.4	0.0	57.	28.2	660.6	245.0
3234.2	1.0	0.0	49.3	30.1	513.1	279.0
3501.8	0.0	0.0	32.4	32.0	405.9	307.5
3860.7	0.0	7.6	0.0	192.6	214.8	1492.5
4108.7	0.0	6.6	0.0	164.8	0.0	1641.8
4283.6	0.0	0.0	22.6	32.0	105.7	637.3

```
TOTAL EMBANKMENT = 8953.2  CUBIC YARDS.
TOTAL EXCAVATION = 8822.9  CUBIC YARDS.
```

Figure 18.--Printer listing of earthwork analysis results.

APPENDIX B

PROGRAM LISTINGS

VARIABLES USED IN THE ROAD PROJECTION PROGRAM, TAPE FILE 2

H = Horizontal Map Scale
C = Contour Interval
X, Y = Tic Mark Coordinates
G = Trial Grade, Percent
M = Computed Map Distance
X1, Y1 = Initial Coordinates
X2, Y2 = Intermediate Coordinates
R = Trial Distance
R1 = Accumulate Road Distance

VARIABLES USED IN THE HORIZONTAL ALINEMENT PROGRAM, TAPE FILE 3

A$ = Alphameric String for Curve Direction
N = Curve Number
I = Plotting Counter
Z = Degree Accumulator
H = Horizontal Map Scale
X, Y = Operating Coordinates
X1, Y1 = Coordinates of Road Starting Point
X2, Y2 = Back Tangent Coordinates
X3, Y3 = Forward Tangent Coordinates
01 = Angle of Back Tangent
S1 = Back Stationing at P.I.
S2 = Length of Back Tangent
02 = Angle of Forward Tangent
A = Polar Angle
D2 = Length of Forward Tangent
0 = Angle Between Tangents
D = Variable for Quadrant Correction
R1 = Curve Radius
T = Curve Tangent
R2 = Degree of
L = Curve Length
P1 = P.C. Distance
P2 = P.T. Distance
P8, P9 = Normalized Values of P.C. Station
P7, P6 = Normalized Values of P.T. Station

S8
S9
S7
S6 = Normalized Values of P.I. Equation

Z2 = Distance Accumulator
R = Polar Distance
D5 = Central Angle Plot Increment
D6 = Deflection Angle
D7 = Deflection Angle Increment

VARIABLES USED IN THE VERTICAL ALINEMENT PROGRAM, TAPE FILE 4

AS(I, 1) = Station
AS(I, 2) = Ground Elevation
B(1) = Station
B(2) = Ground Elevation
B(3) = Grade Elevation
CØ = Counter
I = Array Index Variable
S1 = Distance Accumulator
J = File Counter
K = Array Index Variable
VS(20, 3) = P.V.I. Station and Elevation Array
H = Horizontal Map Scale
C = Contour Interval
E5 = Starting Elevation
E = Elevation Print Variable and Accumulator
X
Y = Operating Coordinates
X1
Y1 = Initial Coordinates
X2
Y2 = Forward Coordinates
S = Distance Between Coordinates
V = Vertical Plot Scale
X = Lable Variable
A = Array Index Variable
E2 = Starting Grade Elevation
S2 = Starting Station
G1 = Back Tangent Grade
E3 = Back P.V.I. Elevation
S3 = Back P.V.I. Station
E4 = Forward P.V.I. Elevation
S4 = Forward P.V.I. Station
G2 = Forward Tangent Grade
L1 = Vertical Curve Length
P1 = P.V.C.
P2 = P.V.T.

S1, S5	=	Normalized Stationing
R1	=	Grade Elevation
R2	=	Rate of Change of Grade
C1	=	Cut or Fill at Centerline

VARIABLES USED IN THE EARTHWORK PROGRAM, TAPE FILE 5

AS(100, 2)	=	Common Buffer
BS(1)	=	Station
BS(2)	=	Ground Elevation
BS(3)	=	Grade Elevation
D(20, 2)	=	Side Slope Break Array
CØ	=	Counter
Q	=	Number of Side Slope Breaks
X3	=	Excavation Accumulator
M3	=	Embankment Accumulator
X2	=	Excavation Volume Between Sections
M2	=	Embankment Volume Between Sections
X	=	Area of Excavation
M	=	Area of Embankment
A	=	File Load Counter
R	=	Roadbed Width
C	=	Cut Slope
F	=	Fill Slope
S	=	Slide Slope
J	=	File Counter
L	=	Centerline Stationing
C1	=	Centerline Fill (Combination Section)
C2	=	Centerline Cut (Combination Section)
D3	=	Offset Distance (Template)
D1, D2	=	Template Distances
H1, H2	=	Template Heights

TAPE FILE 0

```
10 REM LOAD SPECIAL FUNCTION KEYS, TAPE FILE 0
20 LOAD KEY 1
30 DISP "SELECT PROGRAM ON SF KEYS"
40 END
```

TAPE FILE 1, SPECIAL FUNCTION KEYS

SF KEY 0

```
*LOAD2,10,10*
```

SF KEY 1

```
*LOAD3,10,10*
```

SF KEY 2

```
*LOAD4,1,1*
```

SF KEY 3

LOAD5,1,1

SF KEY 4

```
10 PRINT "GENERAL OPERATING INSTRUCTIONS"
20 PRINT "------------------------------------------------------------"
30 PRINT "THIS TIMBER ACCESS ROAD PACKAGE REQUIRES THE DIGITIZER, PLOTTER, AN
40 PRINT "OUTBOARD TAPE CASSETTE.  THE PLOTTER SHOULD BE SET FOR A PLOTTING"
50 PRINT "AREA OF 9 IN. X 14 IN. AND YOU SHOULD HAVE AVAILABLE BOTH  TRANSPAR
60 PRINT "AND CROSS-SECTION PAPER.  THE ROAD PROJECTION AND HORIZONTAL "
70 PRINT "ALIGNMENT ROUTINES REQUIRE THE FORMER, AND THE VERTICAL ALIGNMENT"
80 PRINT "ROUTINE REQUIRES THE LATTER."
90 PRINT
100 PRINT "YOU SHOULD ALSO HAVE AVAILABLE AN EARTHWORK DATA TAPE PREMARKED"
110 PRINT "WITH AN APPROPRIATE NUMBER OF 20 WORD FILES (SAY 200)."
120 PRINT
130 PRINT "SPECIFIC OPERATING INSTRUCTIONS ARE PROVIDED IN THE WRITTEN "
140 PRINT "DOCUMENTATION.  THE SPECIAL FUNCTION KEYS, ALONG WITH VISUAL
150 PRINT "PROMPTING FROM THE DISPLAY AND PRINTER OUTPUT WILL PROVIDE      "
160 PRINT "SUFFICIENT INSTRUCTIONS ONCE THE OPERATOR IS FAMILIAR WITH THE"
170 PRINT "PACKAGE."
180 PRINT
190 PRINT "REMEMBER, THE EARTHWORK ROUTINE PROCESSES DATA COMPILED BY THE"
200 PRINT "VERTICAL ALIGNMENT ROUTINE!   IT WILL PROCESS PREVIOUSLY COMPILED"
210 PRINT "EARTHWORK DATA TAPES."
220 PRINT
230 PRINT "NOW, PROCEED WITH THE SELECTION OF THE APPROPRIATE PROGRAM."
240 PRINT
250 PRINT
260 DISP "SELECT PROGRAM ON SF KEYS"
270 END
```

SF KEY 5

CONT275

SF KEY 6

CONT460

SF KEY 7

CONT2001

SF KEY 8

CONT3001

SHIFTED SF KEY 0

CONT470

SHIFTED SF KEY 1

CONT 690

SHIFTED SF KEY 2

CONT3280

TAPE FILE 2

```
10 REM ROAD PROJECTION ROUTINE,TAPE FILE 2
20 REM PROGRAMMED BY BURKE,PNW,8/73
21 PRINT "ROAD PROJECTION ROUTINE"
24 PRINT "WHEN FINISHED, PRESS-STOP-SHIFT-SF KEY 0"
25 PRINT
26 FIXED 1
30 DISP "MAP SCALE ="; 
40 INPUT H
50 PRINT "MAP SCALE="H"FEET/INCH"
60 DISP "CONTOUR INTERVAL=";
70 INPUT C
80 PRINT "CONTOUR INTERVAL= "C"FEET
90 SCALE 0,14*H,0,9*H
100 DISP "DIGITIZE 1ST TIC MARK"
105 WAIT 2000
110 WRITE (9,*)
120 WAIT 1000
130 ENTER (9,*)X,Y
140 GOSUB 1000
150 DISP "DIGITIZE 2ND TIC MARK"
155 WAIT 2000
160 WRITE (9,*)
170 WAIT 1000
180 ENTER (9,*)X,Y
190 GOSUB 1000
200 R1=0
210 PRINT
220 PRINT "*********************************"
230 PRINT
240 DISP "ENTER TRIAL GRADE (%)";
250 INPUT G
260 PRINT "TRIAL GRADE ="G"%"
270 M=C/(H*G*0.01)
280 DISP "DIGITIZE STARTING POINT"
290 WAIT 1000
300 ENTER (9,*)X1,Y1
310 GOSUB 2000
320 DISP "DIGITIZE TRIAL GRADE LINE"
330 WAIT 1000
335 DISP "PRESS-STOP-CONT470-WHEN DONE"
336 WAIT 3000
340 ENTER (9,*)X2,Y2
350 X=X2-X1
360 Y=Y2-Y1
370 R=SQR(X*X+Y*Y)
380 IF R<M THEN 340
390 WRITE (9,*)
400 WAIT 100
410 WRITE (9,*)
```

```
420 GOSUB 3000
430 R1=R1+R
440 X1=X2
450 Y1=Y2
460 GOTO 340
470 PRINT "GRADE LINE DISTANCE="R1*H"FEET, OR"R1*H/5280"MILES."
480 PRINT
485 DISP "PRESS-CONT200-FOR NEW TRIAL ROAD"
490 STOP
1000 PEN
1010 PLOT X*H,Y*H,-2
1020 CPLOT -0.3,-0.3
1030 LABEL (*)"+"
1040 PEN
1050 RETURN
2000 X=X1
2010 Y=Y1
2020 PLOT X*H,Y*H,-2
2030 RETURN
3000 PLOT X2*H,Y2*H,-2
3010 RETURN
3020 END
```

TAPE FILE 3

```
10 REM  HORIZONTAL ALIGNMENT PROGRAM (HAL), TAPE FILE 3
20 REM  PROGRAMMED BY BURKE, PNW, C.?.
21 DIM A$[10]
22 N=I=Z=0
25 DEG
30 FIXED 0
31 PRINT " HORIZONTAL ALIGNMENT ROUTINE"
40 DISP "MAP SCALE=";
50 INPUT H
60 PRINT "MAP SCALE="H" FEET/INCH"
61 PRINT "PRESS -STOP-SHIFT-OF KEY 1  WHEN FINISHED"
62 PRINT
63 PRINT
70 SCALE 0,14*H,0,9*H
71 PLOT H,9*H,1
72 LABEL (*)"HORIZONTAL ALIGNMENT PLOT"
73 LABEL (*)"SCALE ="H"FEET PER INCH"
80 DISP "DIGITIZE STARTING POINT"
90 WAIT 2000
95 WRITE (9,*)
100 ENTER (9,*)X1,Y1
110 X=X1
120 Y=Y1
125 PEN
130 PLOT X*H,Y*H,-2
140 DISP "DIGITIZE NEXT P.I. POINT"
150 WAIT 1000
```

```
160 WRITE (9,*)
170 ENTER (9,*)X2,Y2
180 X=X2
190 Y=Y2
200 GOSUB 1010
210 X=X2-X1
220 Y=Y2-Y1
230 GOSUB 2000
240 O1=A
250 S1=0
260 S2=R*H
270 DISP 'DIGITIZE NEXT P.I. POINT'
280 WAIT 1000
290 WRITE (9,*)
300 ENTER (9,*)X3,Y3
310 X=X3
320 Y=Y3
330 GOSUB 1010
340 X=X3-X2
350 Y=Y3-Y2
360 GOSUB 2000
370 O2=A
380 D2=R*H
390 O=ABS(O2-O1)
400 IF O<180 THEN 420
410 D=360-O
415 GOTO 430
420 D=O
430 DISP 'CURVE RADIUS & DIRECTION-';
440 INPUT R1,A$
450 T=R1*TAN(D/2)
460 R2=5730/R1
470 L=(D/R2)*100
480 P1=S2-T
490 P2=P1+L
500 S1=P2-T
505 N=N+1
506 GOSUB 3500
510 PRINT
511 Z=Z+D
520 PRINT "CURVE DATA FOR CURVE NO. "N
530 WRITE (15,5000)D
531 IF A$="RIGHT" THEN 540
535 WRITE (15,5002)R1
536 GOTO 550
540 WRITE (15,5001)R1
550 WRITE (15,5003)T
560 WRITE (15,5004)L
561 P8=INT(P1/100)
562 P9=P1-(P8*100)
563 P7=INT(P2/100)
564 P6=P2-(P7*100)
565 S8=INT(S1/100)
566 S9=S1-(S8*100)
567 S7=INT(S2/100)
```

```
568 S6=S2-(S7*100)
570 WRITE (15,5005)P8,P9
580 WRITE (15,5006)P7,P6
590 WRITE (15,5007)S8,S9,S7,S6
610 PRINT
620 PRINT
630 GOSUB 2000
640 Y2=Y3
650 X2=X3
660 01=02
670 S2=S1+D2
680 GOTO 270
690 PRINT "+++++++++++++++++++++++++++++++++"
691 PRINT "HORIZONTAL ALIGNMENT SUMMARY"
692 PRINT "TOTAL NUMBER OF CURVES ="N
693 PRINT "TOTAL CURVATURE ="Z"DEGREES"
694 Z2=S1+(D2-T)
695 PRINT "TOTAL L-LINE DISTANCE ="Z2"FEET"
696 FIXED 2
697 PRINT "OR"Z2/5280"MILES."
698 STOP
1000 PEN
1010 PLOT X*H,Y*H,-2
1020 RETURN
2000 R=SQR(X*X+Y*Y)
2010 A=ATN(Y/(X+(1E-90)*(X=0)))+2*SGN(ATN1E+99*(X<0))
2020 RETURN
3000 PEN
3010 X=X2+((T/H)*COS(01+180))
3020 Y=Y2+((T/H)*SIN(01+180))
3030 GOSUB 1010
3040 IF A$="LEFT" THEN 3070
3050 D5=-D/16
3060 GOTO 3080
3070 D5=D/16
3080 D6=01+D5
3090 X=X+(((L/8)/H)*COSD6)
3100 Y=Y+(((L/8)/H)*SIND6)
3110 GOSUB 4010
3120 I=I+1
3130 IF I=8 THEN 3170
3140 D7=2*D5
3150 D6=D6+D7
3160 GOTO 3090
3170 X=X3
3180 Y=Y3
3190 GOSUB 1000
3191 I=0
3200 RETURN
3500 PLOT X2*H,Y2*H,1
3510 CPLOT -1,-1
3520 LABEL (*)N
3530 PEN
3540 RETURN
4000 PEN
```

```
4010 PLOT [illegible]
4020 RETURN
5000 FORMAT "DELTA =",F4.0," DEGREES"
5001 FORMAT "RADIUS =",F4.0," FEET RIGHT"
5002 FORMAT "RADIUS =",F4.0," FEET LEFT"
5003 FORMAT "TANGENT =",F4.0," FEET"
5004 FORMAT "LENGTH =",F4.0," FEET"
5005 FORMAT "P.C.= STA.",F4.0,"+",F3.0
5006 FORMAT "P.T.= STA.",F4.0,"+",F3.0
5007 FORMAT "P.I. EQ.= STA.",F4.0,"+",F3.0,"  AHD.= STA.",F4.0,"+",F3.0,[illegible]
6000 END
```

TAPE FILE 4

```
1 COM A$[100,2],B$[3],C[illegible]
10 REM VERTICAL ALIGNMENT ROUTINE, TAPE FILE 4
20 REM  PROGRAMMED BY [illegible]
30 FIXED 0
40 I=S1=[illegible]
41 DIM V$[20,[illegible]]
50 PRINT "VERTICAL ALIGNMENT ROUTINE"
51 PRINT "USE SF KEYS [illegible] FOR VARIOUS OPERATIONS"
52 PRINT "******INSTALL CARTRIDGE DATA TAPE OR OUTBOARD CASSETTE*******"
60 DISP "MAP SCALE =";
70 INPUT H
80 PRINT "MAP SCALE ="H"FEET PER INCH"
90 DISP "CONTOUR INTERVAL =";
100 INPUT C
110 PRINT "CONTOUR INTERVAL ="C"FEET"
120 DISP "STARTING ELEVATION =";
130 INPUT E5
131 E=E5
132 GOSUB 1000
140 PRINT "STARTING ELEVATION ="E"FEET"
150 PRINT
155 PRINT "---------------------------------------"
160 DISP "DIGITIZE PROFILE POINTS"
170 WAIT 1000
180 ENTER (9,*)X1,Y1
185 REM     ASSUMES UP
190 ENTER (9,*)X2,Y2
200 X=X2-X1
210 Y=Y2-Y1
220 S=SQR(X*X+Y*Y)*H
225 S1=S1+S
230 E=E+C
240 GOSUB 1000
250 X1=X2
260 Y1=Y2
270 GOTO 190
275 REM        UP TO DOWN
280 DISP "[illegible] =";
290 INPUT [illegible]
```

```
300 ENTER (9,*)X2,Y2
310 X=X2-X1
320 Y=Y2-Y1
330 S=SQR(X*X+Y*Y)*H
340 S1=S1+S
350 GOSUB 1000
360 X1=X2
370 Y1=Y2
380 ENTER (9,*)X2,Y2
390 X=X2-X1
400 Y=Y2-Y1
410 S=SQR(X*X+Y*Y)*H
420 E=E-C
430 S1=S1+S
440 GOSUB 1000
450 GOTO 360
460 REM       DOWN TO UP
470 DISP "ELEVATION :";
480 INPUT E
490 ENTER (9,*)X2,Y2
500 X=X2-X1
510 Y=Y2-Y1
520 S=SQR(X*X+Y*Y)*H
530 S1=S1+S
540 GOSUB 1000
550 X1=X2
560 Y1=Y2
570 GOTO 190
1000 I=I+1
1010 A[I,1]=S1
1020 A[I,2]=E
1040 RETURN
2001 DEG
2010 DISP "ENTER HOR.& VERT. SCALE";
2020 INPUT H,V
2030 SCALE -H/9,13.5*H,E5-V/4,E5+9*V
2031 PLOT H,E5+8.5*V
2032 LABEL (*)"ROAD PROFILE PLOT"
2033 LABEL (*,1.3,1.7,0,9/14)"HOR. SCALE: 1 IN.=";H;"FEET"
2034 LABEL (*,1.3,1.7,0,9/14)"VERT. SCALE: 1 IN.=";V;"FEET"
2040 OFFSET H/2,V/2
2045 XAXIS E5,H,0,13*H
2050 YAXIS 0,V,E5,E5+8*V
2055 OFFSET H/2,-V/2
2065 FOR X=0 TO 13*H STEP H
2070 PLOT X,E5+40,-1
2075 CPLOT 0,-0.3
2080 LABEL (*,1,1.7,90,9/14)X
2085 NEXT X
2090 OFFSET -H/2,V/2
2095 FOR Y=E5 TO E5+8*V STEP V
2100 PLOT 200,Y,-1
2105 CPLOT 0,-0.3
2110 LABEL (*,1,1.7,0,9/14)Y
2115 NEXT Y
2140 OFFSET H/2,V/2
```

```
2150 FOR A=1 TO I
2160 PLOT A[A,1],A[A,2]
2170 PRINT A[A,1];A[A,2]
2180 NEXT A
2185 PEN
2186 C0=I
2190 STOP
3000 REM     VERTICAL CURVE ROUTINE
3001 I=1
3005 FIXED 1
3010 PRINT "                              VERTICAL CURVE DATA"
3011 PRINT
3013 PRINT TAB5"STATION"TAB21"GROUND"TAB31"GRADE"TAB41"CUT"TAB51"FILL"
3014 PRINT
3020 DISP "ENTER STARTING ELEV.(STA.0+00)";
3030 INPUT E2,S2
3031 PRINT "   0     "TAB20,E2;TAB30,E2;TAB40"0"TAB50"0"
3032 PLOT S2,E2,-2
3036 B[1]=S2
3037 B[2]=E2
3038 B[3]=E2
3039 GOSUB 4030
3040 DISP "ENTER PVI ELEV.& STA.";
3050 INPUT E3,S3
3051 K=K+1
3052 V[K,1]=S3
3053 V[K,2]=E3
3060 G1=((E3-E2)/(S3-S2))*100
3070 DISP "ENTER NEXT PVI ELEV.& STA.";
3080 INPUT E4,S4
3090 G2=((E4-E3)/(S4-S3))*100
3100 DISP "ENTER V.C. LENGTH  STATIONS";
3109 INPUT L1
3110 V[K,3]=L1
3111 K=K+1
3112 V[K,1]=S4
3113 V[K,2]=E4
3120 P1=(S3-(L1/2)*100)
3130 P2=(S3+(L1/2)*100)
3140 I=I+1
3141 IF A[I,1]>P2 THEN 3240
3150 S1=INT(A[I,1]/100)
3151 S5=A[I,1]-(S1*100)
3160 E=A[I,2]
3170 IF A[I,1]>P1 THEN 3220
3180 R1=E2+(A[I,1]-S2)*G1*0.01
3185 PLOT A[I,1],R1,-2
3190 IF R1<E THEN 3215
3200 C1=R1-E
3201 PRINT S1;TAB10,"+"S5;TAB20,E;TAB30,R1;TAB50,C1
3205 GOSUB 4000
3210 GOTO 3140
3215 C1=E-R1
3216 PRINT S1;TAB10,"+"S5;TAB20,E;TAB30,R1;TAB40,C1
3217 GOSUB 4000
```

```
3218 GOTO [illegible]
3220 X=[illegible]
3221 R2=(G2-G1)[illegible]L1
3222 R1=E2+((P1-S2)*G1*0.01)+[illegible]G1[illegible]*X
3230 GOTO 3185
3240 E2=E3
3241 E3=E4
3249 S2=S3
3250 S3=S4
3260 G1=G2
3265 I=I-1
3270 GOTO 3070
3280 I=I+1
3285 E=A[I,2]
3290 R1=E2+(A[I,1]-S[illegible])*G1*0.01
3295 PLOT A[I,1],R1,-2
3300 S1=INT(A[I,1]/100)
3310 S5=A[I,1]-(S1*100)
3320 IF R1<E THEN 3360
3330 C1=R1-E
3340 PRINT S1;TAB10,"+";S5;TAB20,E;[illegible]R1;TAB50,[illegible]
3345 GOSUB 4000
3350 GOTO 3380
3360 C1=E-R1
3370 PRINT S1;TAB10,"+";S5;TAB20,E;[illegible]R1;TAB40,[illegible]
3375 GOSUB 4000
3380 I=I+1
3390 GOTO 3285
4000 B[1]=A[I,1]
4010 B[2]=A[I,2]
4020 B[3]=R1
4030 J=J+1
4040 STORE  DATA #5,J,B
4045 IF J=C0 THEN 5010
4050 RETURN
5010 PEN
5011 PRINT
5012 PRINT
5013 PRINT "STATION",TAB1[illegible]"E.V.[illegible]"[illegible]TAB30,"[illegible]LENGTH"
5014 PRINT "[illegible]"
5015 FOR N=1 TO K-1
5016 PRINT V[N,1],TAB1[illegible]V[N,2],TAB[illegible][N,3]
5017 NEXT N
5018 STOP
5020 END
6000 J=0
6010 J=J+1
6020 LOAD  DATA #5,J,B
6030 PRINT B[1][illegible]
6040 GOTO [illegible]
6050 STOP
```

APE FILE 5

```
 COM A$[100,2],B$[3],C0
 REM      EARTHWORK ANALYSIS PROGRAM, TAPE FILE 5
 REM      PROGRAMMED BY BURKE, PNW, 12/73-3/74
10 FIXED 1
20 X3=M3=C1=C2=X2=M2=X=M=A=K=0
21 J=1
30 DIM D$[20,2]
40 DISP "ENTER ROADBED WIDTH";
50 INPUT R
60 DISP "ENTER CUT SLOPE";
70 INPUT C
80 DISP "ENTER FILL SLOPE";
90 INPUT F
100 DISP "HOW MANY SIDE SLOPE BREAKS";
102 INPUT Q
104 FOR I=1 TO Q
106 DISP "ENTER SIDE SLOPE AND ENDING STA.";
108 INPUT D[I,1],D[I,2]
110 NEXT I
115 PRINT
120 PRINT "ROADBED WIDTH ="R;"FEET"
130 PRINT "CUT SLOPE RATIO ="C":1"
140 PRINT "FILL SLOPE RATIO ="F":1"
150 FOR I=1 TO Q
152 PRINT "SIDE SLOPE OF"D[I,1]*100;"PERCENT ENDS AT STA."D[I,2]
153 NEXT I
160 PRINT
161 PRINT TAB30"EARTHWORK QUANTITIES"
162 PRINT
165 PRINT TAB14"CENTER-LINE"TAB32"AREA (SQ.FT.)"TAB52"VOLUME (CU.YD)"
170 PRINT "STATION"TAB11"CUT"TAB21"FILL"TAB32"EXC"TAB42"EMB"TAB52"EXC TAB62"EM
180 PRINT
185 K=K+1
190 LOAD  DATA #5,J,B
195 A=A+1
196 IF A>C0 THEN 1002
199 IF B[1]>D[K,2] THEN 205
200 D1=B[1]
201 S=D[K,1]
203 GOTO 210
205 K=K+1
207 S=D[K,1]
210 IF (B[2]+(S*R/2))<B[3] AND (B[2]-(S*R/2))<B[3] THEN 440
220 IF B[2]+(S*R/2)>B[3] AND B[2]-(S*R/2)>B[3] THEN 600
230 REM SIDEHILL SECTION
240 IF B[2]>B[3] THEN 280
250 C1=B[3]-B[2]
260 D3=C1/S
270 GOTO 300
280 C2=B[2]-B[3]
290 D3=C2/S
300 X=((R/2+D3)*(-C*(R/2+D3)...
```

```
310 M=((R/2+D3)*(-C*(R/2-D3)) [illegible]
320 IF J=1 THEN 370
330 X2=(((X+X1)/2)*(B[1]-L))/27
340 M2=(((M+M1)/2)*(B[1]-L))/27
350 X3=X3+X2
360 M3=M3+M2
370 GOSUB 1000
380 C1=C2=X2=M2=0
390 L=B[1]
400 X1=X
410 M1=M
420 J=J+1
425 IF J>C0 THEN 1002
430 GOTO 190
440 REM         FILL SECTION
450 C1=B[3]-B[2]
460 D1=C1+((R/2)*F)/(F+S)
470 D2=C1+((R/2)*F)/(F-S)
480 H1=S*D1
490 H2=S*D2
500 M=0.5*(C1*(D1+D2)+(R/2*(H1+H2)))
505 X=0
510 IF J=1 THEN 540
520 M2=(((M+M1)/2)*(B[1]-L))/27
530 M3=M3+M2
532 X2=(((X+X1)/2)*(B[1]-L))/27
534 X3=X3+X2
540 GOSUB 1000
550 C1=C2=X2=M2=0
560 L=B[1]
570 M1=M
572 X1=X
580 J=J+1
585 IF J>C0 THEN 1002
590 GOTO 190
600 REM          CUT SECTION
610 C2=B[2]-B[3]
620 D1=C2+(R/2*C)/(C-S)
630 D2=C2+(R/2*C)/(C+S)
640 H1=D1+S
650 H2=D2+S
660 X=0.5*(C2*(D1+D2)+(R/2*(H1+H2)))
665 M=0
670 IF J=1 THEN 700
680 X2=(((X+X1)/2)*(B[1]-L))/27
690 X3=X3+X2
692 M2=(((M+M1)/2)*(B[1]-L))/27
694 M3=M3+M2
700 GOSUB 1000
710 C1=C2=X2=M2=0
720 L=B[1]
730 X1=X
732 M1=M
740 J=J+1
```

```
745 IF J<0 THEN 1002
750 GOTO 190
1000 PRINT B[1];TAB10,C2;TAB20,C1;TAB30,X;TAB40,M;TAB50,X2;TAB60,M2
1001 RETURN
1002 PRINT
1003 PRINT
1004 PRINT "TOTAL EMBANKMENT ="M;"CUBIC YARDS."
1005 PRINT "TOTAL EXCAVATION = "X;"CUBIC YARDS."
1006 DISP "ENTER SIDE SLOPE AND ENDING STA.";
1007 PRINT
1010 STOP
1030 END
```

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

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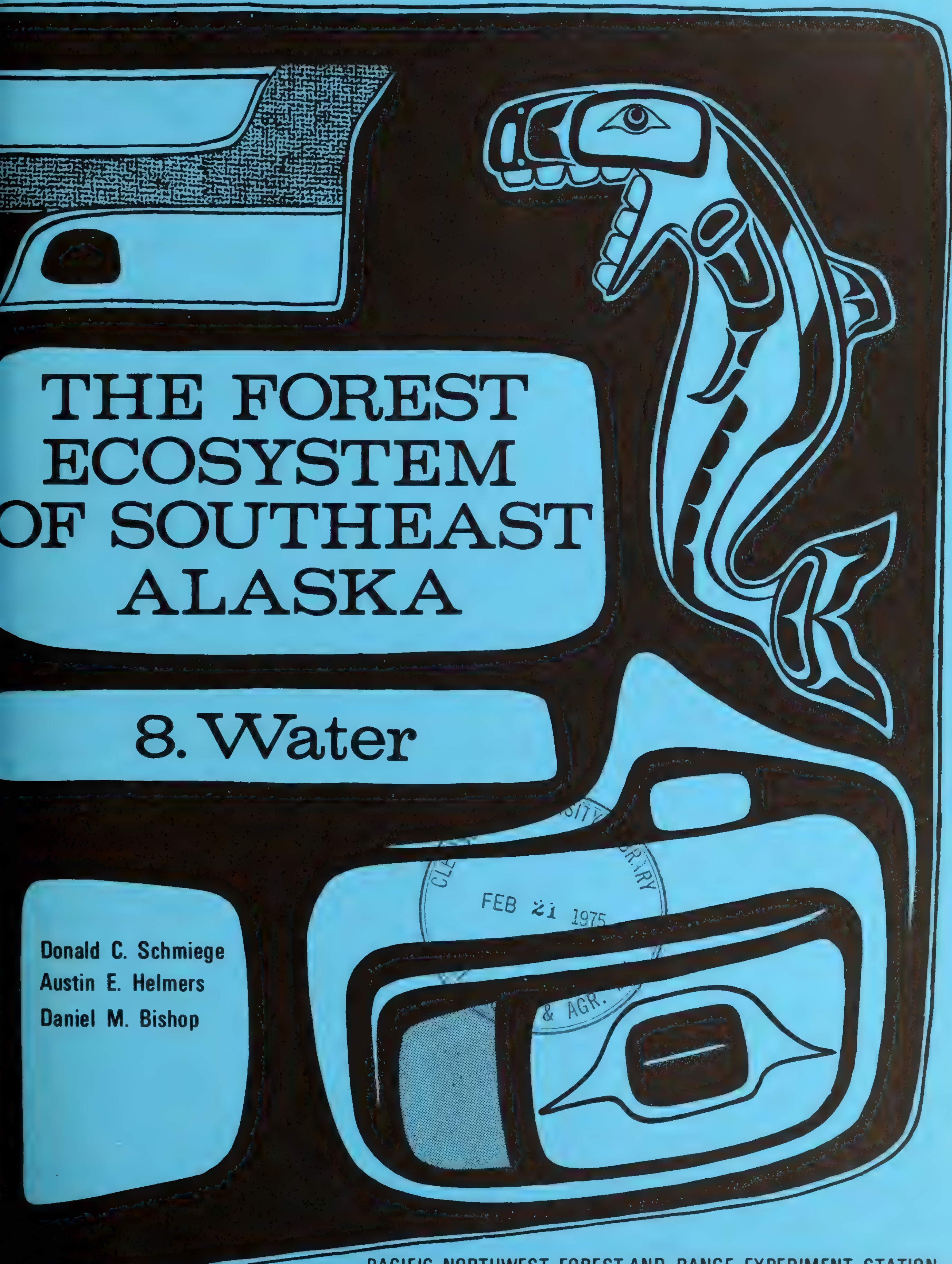

THE FOREST ECOSYSTEM OF SOUTHEAST ALASKA

8. Water

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FEB 21 1975

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE

CONTENTS

ABSTRACT

One of the most striking characteristics of southeast Alaska is the abundance of water. Large glaciers, icefields, and thousands of streams result from heavy precipitation throughout the year.

Published and unpublished data on water regimen, temperature, sedimentation, and chemistry are combined. These serve as a basis for understanding how this valuable resource may be used and protected so that high quality water may always be abundant and available. A brief section on needed research is included.

Keywords: Watershed Management, water quality research, Alaska.

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PREFACE

This is the eighth in a series of publications summarizing knowledge about the forest resources of southeast Alaska.

Our intent in presenting the information in these publications is to provide managers and users of southeast Alaska's forest resources with the most complete information available for estimating the consequences of various management alternatives.

In this series of papers, we summarize published and unpublished reports and data as well as the observations of resource scientists and managers developed over years of experience in southeast Alaska. These compilations will be valuable in planning future research on forest management in southeast Alaska. The extensive lists of references will serve as a bibliography on forest resources and their utilization for this part of the United States.

Previous publications in this series include:

1. The Setting
2. Forest Insects
3. Fish Habitats
4. Wildlife Habitats
5. Soil Mass Movement
6. Forest Diseases
7. Forest Ecology and Timber Management

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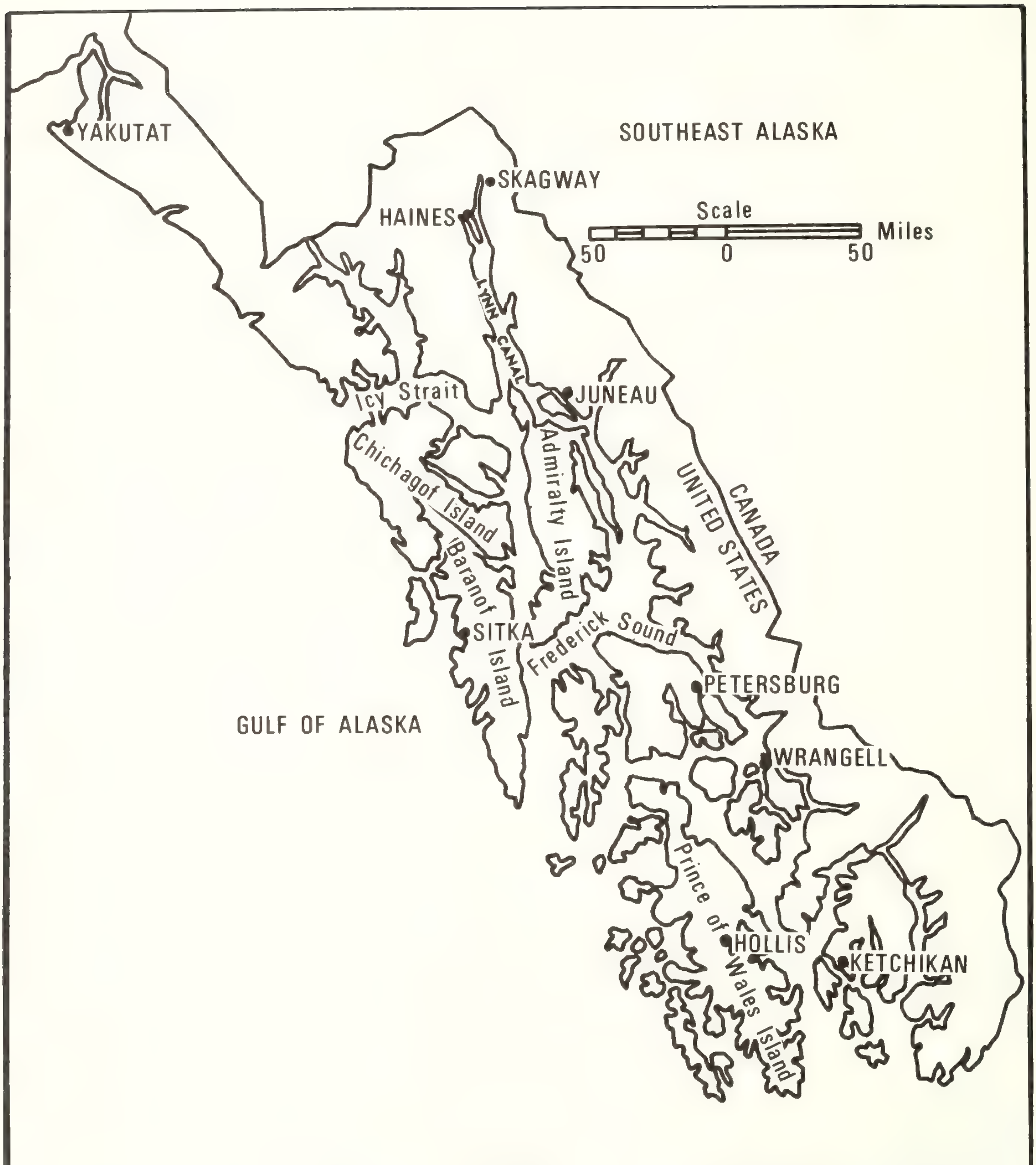

Map of southeast Alaska east of the 141st meridian.

INTRODUCTION

Southeast Alaska is a water-oriented region. It is nearly 400 miles long and about 120 miles wide from the Canadian boundary to the western shores of the islands of the Alexander Archipelago. The total land area is 35,527 square miles and includes hundreds of islands (Federal Power Commission and U.S. Forest Service 1947). There are 9,000 miles of shoreline. From the mainland and the great variety of islands arise thousands of streams and lakes. There are also numerous bays and estuaries with a variety of oceanographic features. It has been estimated that there are more than 1,100 salmon spawning streams of which the more important have been described and cataloged (U.S. Department of Interior 1959, 1963a, 1963b, 1965a, 1965b). Glacial and alluvial gravel deposits provide abundant spawning areas for the millions of salmon and trout that migrate into the streams annually.

From 1911 to 1945, 51 stream gaging stations operated throughout southeast Alaska. Most streams in southeast Alaska have small short drainages, and wide ranges in discharge. The mean annual discharge in cfsm (cubic feet per second per square mile) ranged from 8.5 to 19.1. The median discharge was 13.8 cfsm (Federal Power Commission and U.S. Forest Service 1947).

Icefields are nearly continuous on the Coast Range of the mainland, and there are many glaciers that empty into the main fiords. Water and ice have sculptured a rugged mountain scene of unrivaled beauty (fig. 1). Even the saltwater which forms the inland passage of the Alexander Archipelago is in constant motion due to the large tides.

Figure 1.--A mountain lake on the mainland of southeast Alaska.

Heavy precipitation during most months supplies a large runoff volume that is carried to the sea by streams of all sizes. This streamflow provides freshwater habitat that supports valuable commercial and recreational fisheries. The abundant rainfall typical throughout southeastern Alaska supports dense stands of western hemlock and Sitka spruce that are often referred to as temperate "rain forests." Muskegs are a common feature of the landscape from sea level to ridgetops.

Many mainland rivers have their origins in the glaciers and snowfields of the Coast Range and St. Elias Mountains. Drainage is generally westward except at the northern end of the region where drainage is also southward to Lynn Canal and Glacier Bay. Some of the largest rivers, such as the Alsek, Taku, and Stikine, have glacial origins in the Yukon Territory or the plateaus of British Columbia. The Chilkat, Skagway, Speel, Whiting, Unuk, Chickamin, and Salmon Rivers arise in snowfields and glaciers of mountain range headwaters which reach into Canada (fig. 2). The mainland slopes are steep, rocky, and deeply incised by glaciation so that there are many small drainage basins adjacent to the tidal inlets and bays that indent the coastline. Some of these smaller streams have glaciers at their headwaters. Many have lakes fed by semipermanent snowfields or have lakes along their courses.

Figure 2.--The Chickamin River--its headwaters drain glaciers in British Columbia.

The watersheds on the islands of the Alexander Archipelago drain mainly to the east or west directly into tidal waters. The westerly slopes draining toward the ocean are more gradual than the drainage slopes toward the mainland so that generally the streams flowing westward are longer.

One of the largest streams on the islands is the Hasselborg River, on Admiralty Island, with a drainage area of 107 square miles. Other large streams are the Medvetcha and Maksoutof Rivers, both of which drain westward on Baranof Island, and Thorne River on Prince of Wales Island.

STREAMFLOW REGIMEN

The average surface water runoff for the main United States and Canadian contributing basins east of the 141st meridian in southeastern Alaska is about 601,000 cfs (Wilson and Iseri 1969). The drainage area is about 77,900 square miles; therefore the unit runoff for the basins combined is roughly 7.7 cfsm. However, since a large part of the drainage area for many of the larger mainland streams is in Canada, there is a net water production from southeastern Alaska of about 480,630 cfs (table 1).

Table 1.--River discharge to the sea from Alaska east of the 141st meridian, and the flow of water from Canada to southeast Alaska

River basin	River total discharge	Flow, Canada to Alaska	Net flow from within Alaska
	cfs	cfs	cfs
Chickamin	8,000	1,600	6,400
Unuk	9,000	6,200	2,800
Stikine	61,000	54,600	6,400
Whiting	10,000	8,000	2,000
Speel	3,700	370	3,330
Taku	15,000	11,200	3,800
Alsek	45,000	34,500	10,500
Chilkat	8,000	3,900	4,100
Total, east of 141st meridian	601,000	120,370	480,630

Source: Wilson and Iseri (1969).

The quantity of streamflow depends first on precipitation and then on basin characteristics. The latter include factors that can be modified by land management practices such as logging, roadbuilding, mining, and community developments and expansion.

The unit runoff is high, but the relationship of runoff to precipitation is poorly understood because most precipitation measurements are from low elevation stations. Such stations do not show the large amounts of precipitation occurring at higher elevations.

Surface runoff in southeast Alaska from lower elevation basins is about 60-100 inches annually and 150-200 inches from intermediate and higher elevations. Streamflow records near sea level (Feulner et al. 1971) showed that basin runoff exceeds precipitation. Waananen (1950) stated that "Streamflow records indicate that maximum precipitation at the higher altitudes in the southern portion exceeds 250 inches annually." Walkotten and Patric (1967) measured a 0.02-inch increase in rain per 100-foot increase of elevation near Hollis on Prince of Wales Island. Murphy and Schamach (1966) estimated that the normal annual precipitation at 3,400-foot elevation near Juneau should be at least 285 inches, compared with the normal 90.98 inches at the Juneau city gage exposed 71 feet above sea level.

An analysis of snow pit data and rainfall measurements from various points on the Juneau icefield has provided an estimate of high elevation precipitation. For example, on Ptarmigan and Lemon Glaciers near Juneau, a number of pits measured near the time of maximum snow accumulation indicated from 75-114 inches of water equivalent (above the previous year's surface) at elevations between roughly 3,000 and 3,900 feet. Summer rainfall in the vicinity of these glaciers can range from 30-60 inches. The magnitude of annual precipitation thus could be 160 or more inches, compared with a sea level normal of 55 inches at the Juneau Airport. This rough analysis does not take into account the likely effects of wind and subsequent snow transport. Upper-elevation (4,000-5,000 feet) precipitation in this area probably should average more than 200 inches, because the average discharge of Lemon Creek, which is supported in part by these glaciers, is equivalent to 174 inches annually. As this runoff includes flow from three diminishing glaciers above the gaging stations, an excess of runoff over precipitation should be expected even if precipitation could be accurately measured.

The bulk of what is known about water production in southeastern Alaska consists of the records published by the U.S. Geological Survey. As of 1970, the U.S. Geological Survey published daily discharge data and several summaries for 30 streams that have 5 or more years of record. Record length was up to 52 years. The area of these gaged watersheds ranges from 2.5 to 226 square miles. Additional scattered, unpublished data are available from the U.S. Geological Survey and from study data on timber-salmon relationships on file at the Forestry Sciences Laboratory at Juneau.

James (1956) summarized southeast Alaska streamflow based on studies on Prince of Wales Island:

> The combination of steep slopes, heavy precipitation and limited water-holding capacity of watersheds in southeast Alaska results in fairly unstable characteristics of flow. This is especially true in streams without sizeable lakes in their watersheds which afford natural regulation of streamflow. Discharge responds quickly to rainfall intensity and fluctuates quite rapidly between maximum and minimum values within relatively short periods of time....
>
> Heavy precipitation during October, November, and early December causes numerous floods which produce a highly fluctuating discharge hydrograph. Cold weather and snowfall from December until April are responsible for a declining flow and the shaping of a hydrograph which shows a diurnal peak and trough corresponding

> to the crest made by melted snow. When the snow is gone, the flow declines and the hydrograph drops in a long, flat curve on which the occasional summer storm of June, July, and August places minor peaks. Storm frequency and intensity generally begin to increase in September.
>
> Maximum water loss takes place through evaporation and transpiration in Southeast Alaska from May through September During May, especially at the lower elevations, rainfall is generally heavy, air temperatures increase, vegetation begins to grow, and evaporation and transpiration rates increase. Precipitation generally decreases to its lowest value in June, but snowmelt holds the runoff pattern up. Rainfall increases each month from July through October. Though precipitation is greater during July and August than in June...streamflow for these two months is considerably less than in June. This results primarily from loss of water through increased evapo-transpiration rates.
>
> Evaporation and transpiration rates decrease considerably in October and stream runoff swings sharply upward. Precipitation is heavy during this month--generally the wettest month in Southeast Alaska...and quite rapidly satisfies any soil moisture deficit which might have resulted from evaporation and transpiration. Stream discharge generally continues to increase through the months of November, and a portion of December, until cold weather and snowfall result in a storage of precipitation in the form of snow. Rains are quite common during this season when the watersheds may be frozen and snow-covered, and associated runoff is rapid.
>
> ...Snow first begins to melt on the Maybeso Creek drainage some time in April or early May. It swells stream discharge until some time in July....The magnitude of stream runoff during the months of May and June is considerably out of proportion to precipitation intensities received during these months. A considerable quantity of this total runoff comes from snowmelt.

A typical discharge pattern for a nonglacial stream is shown in figure 3. The extreme runoff gaged in 1970 was 329 inches from Sashin Creek, near Little Port Walter on Baranof Island, where the sea level precipitation was 265 inches for the period. This is another example of the common southeast Alaska situation in which basin runoff exceeds sea level precipitation. Elevation-precipitation relationships should affect runoff. However, techniques for estimating runoff are of limited reliability because precipitation patterns and relationships are poorly understood (Childers 1970, p. 36).

Glaciers are a major component of the water resource, and one that is highly significant along the mainland where glaciers and icefields occupy about 2,000 square miles of the highlands (Field 1958). Glaciers regulate streamflow.

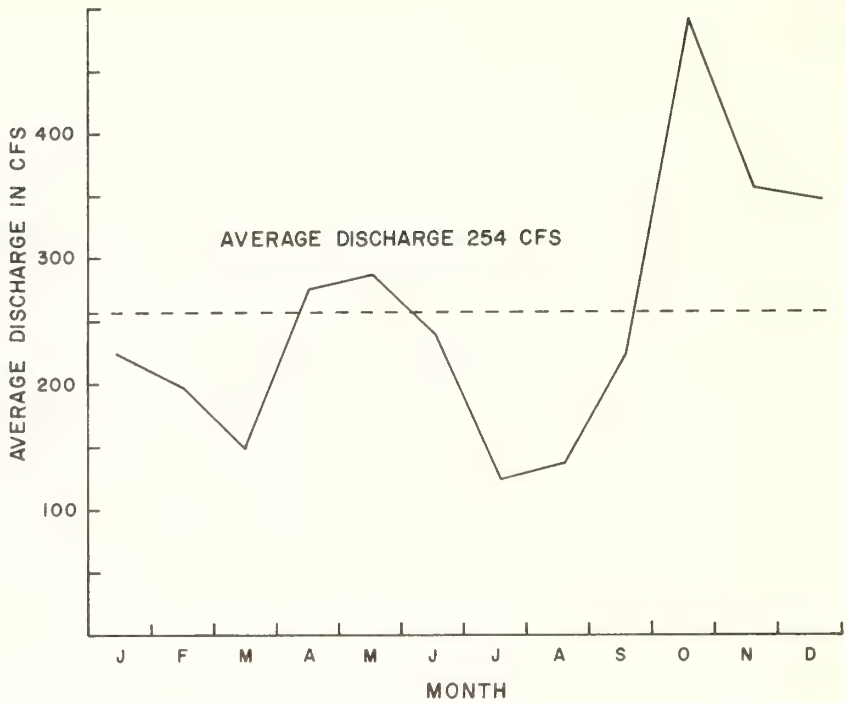

Figure 3.--Average monthly discharge for Harris River, 1950-64. This stream reflects the typical seasonal discharge of southeast Alaska streams. The below average discharges of the January-March period are the result of snow and ice accumulation. The rise above average during the April-June period is due primarily to snowmelt. Precipitation is relatively low and evapotranspiration high in the summer, resulting in a second low flow period. Heavy rains associated with fall storms result in peak flows.

Streamflow from streams with glacier systems in their basins in the Juneau area peak at about 23 and 24 percent of the water-year runoff in July and August, primarily in response to snow and ice melting. Snowmelt also contributes to the 15-percent runoff in June; rain probably is a factor in the 20-percent runoff amount for September. The higher elevations and consequent lower temperatures of glacierized watersheds cause a rapid drop in runoff beginning in October and a low base flow in December through April. The low flow probably is also related to the bare rock and coarse mantle materials common at the upper elevations. Runoff from glacier-free basins in the Juneau area peak at about 13 and 14 percent of the year's runoff in May and June in response to snowmelt and peak again at approximately 14 percent in September due to rain. Summer flows are quite uniform, with about 12 percent maintained for July, August, and October.

Timber harvesting is the land use activity most likely to significantly affect the quantity of streamflow. Since studies of such effects have been limited to research on clearcutting-salmon relationships, it is worthwhile to consider also general experience elsewhere which has local application.

According to Hewlett and Hibbert (1961, p. 6 and 16),

> There can be little doubt that in most well-watered lands conversion of mature forest to low-growing vegetation will increase supply of water to streams....When considered independently of other factors, such as aspect, elevation, soil depth, and precipitation, first-year increases in yield seem roughly related to the percent of the fully-developed stand removed or cut down....First-year increases in the order of 5 to 16 inches may be expected at Coweeta [North Carolina] after complete clear-cutting of a mature hardwood forest....Experiments of all types within the temperate zones of the world, neglecting Coweeta, suggest increases in streamflow up to about 10 inches per year as a result of clear-cutting forested watersheds, but the average would seem to be about half this amount.

Meehan et al. (1969, p. 2) summarized subsequent experience:

> Rowe (1963) reported annual increases, depending on rainfall, ranging from 4.4 to 14.4 area-inches following removal of riparian woodland in California. Reinhart et al. (1963) reported increases of 1 to 5 inches following logging; the increased flows were roughly proportional to stand removal. For a tributary of Oregon's McKenzie River, Rothacher (1965) found 12 to 28 percent increased low flows following 30-percent vegetation removal, and 85-percent increase following 80-percent removal. On an Arizona watershed, conversion of 80 acres of moist-site forest to grass increased streamflow about 55 percent (Rich 1965). Eschner and Satterlund (1966) reported a 7.72-inch decrease in annual streamflow between 1912 and 1950 when forest density notably increased on the Sacandaga River watershed in New York. Analysis of discharge measurements by Riggs (1965) for nine small streams in Virginia indicated that discharge per square mile was directly related to the percentage of the drainage basin cleared of trees and brush. Clearing land along channels seemed to produce a greater effect on discharge than clearing over the basin generally. This effect of clearing was most pronounced at extremely low levels of discharge and became negligible at high discharges.

Water level studies from 1949 to 1964 made on two streams, at Hollis, before, during, and after clearcutting of 20 to 25 percent of the watersheds did not show changes in water yield (Meehan et al. 1969). A response to the clearcutting undoubtedly occurred, but it was too small to be detected by the available stream gaging conditions.

It appears that one-fourth of the watershed area, at lower elevations only, might be clearcut without substantially changing the quantity of water production. However, there may be changes in pattern of runoff which are often critical to fish. As large proportions of watershed areas are cut, involving increasingly higher elevations, undoubtedly there will be greater changes in water production.

WATER QUALITY

SEDIMENT

Streamload consists of suspended material and bedloads carried within a water column or along the streambed. Sediment may be suspended as part of the freeflowing, above-streambed water of a stream, and in this form it causes the turbid or murky appearance of the water. Bed material occurring in the stream may be the result of suspended or bedload movement or both. Suspended sediment is the only fraction of streamload that has been sampled to a major extent in southeast Alaska.

Another form of stream transported material is called bedload, which includes particles rolling or bouncing downstream. Although recognized as important, this bedload fraction of streamload has not been adequately sampled, largely because of the great difficulties in obtaining meaningful results.

Sediment in streams comes from both geologic processes and man's activities. Southeast Alaska is a geologically youthful region in which soil and debris movements and stream system development are particularly active. These natural processes create sediment. Steep terrain and large amounts of rainfall make the land sensitive, in terms of sediment production, to such activities as road construction and timber harvesting. Ameliorating influences include coarse-textured soils with thick organic surface layers, high permeability, high infiltration, and conditions that favor rapid revegetation of disturbed soil. There also seems to be little overland flow (Stephens 1966).

Sampling of streambed gravels and deposited sediments by various agencies over a number of years shows that composition by size class may include particles from silts and fine sands through large boulders and shapes that range from angular to nearly spherical. The composition of streambed materials as well as ranges of stream energy affects the stability of a stream bottom. These parameters therefore affect the stability of a stream as habitat for fish.

Over the past 50 years, the basic concepts concerning mechanics of streamflow and the effects of various stream parameters (depth, gradient, velocity, bedload, channel configuration, etc.) on sediment transport and deposition have been developed. Gross differentiation of streams according to gravel stability can be made (Gilbert 1914, Rubey 1938, Kalinske 1947, Brooks 1958, Colby 1961).

The principles relating stream parameters to sediment transport and deposition were developed from observations and measurement of streams in watersheds much older geomorphologically than those in southeastern Alaska. The gradients and velocities were much lower, the flows more constant, and the sediment load finer. Consequently, although the basic concepts of stream mechanics and sediment transport remain the same for all streams, quantitative results obtained in these other areas cannot be applied directly to conditions in southeastern Alaska.

Suspended sediment loads of nonglacial streams in southeast Alaska are extremely low, even in heavily logged watersheds. For instance, in two watersheds near Hollis where clearcuts exceeded 2,000 acres in size, suspended sediment during and following logging in the Harris River never exceeded 3.7 ppm (parts per million) under average flow conditions or 148 ppm during peak flows, and in Maybeso Creek 7 ppm during average flow or 38 ppm during peak flows. Such low suspended sediment levels are due to the unique watershed

characteristics, namely, low intensity rainfall; soils with thick, tough, organic surfaces; extremely rapid infiltration and percolation rates; and lack of surface runoff except on badly disturbed ground. The difficulty of obtaining precise measurements in the field may also have been a factor.

As a basis for understanding the behavior of suspended sediments in southeast Alaska streams, an examination was made of suspended sediment data as of September 30, 1970, for 45 sample streams. These data were taken from U.S. Geological Survey water quality reports (288 samples) and from values published by the Institute of Northern Forestry[1] for Hollis area streams (230 samples).

Using these data, along with actual experience on many of the basins that were sampled, a classification system was devised that rated streams according to differences or similarities in origin of suspended sediment. This rating system provides a tool that can be useful in developing plans for prevention or regulation of suspended sediment, provided it is recognized that the system is tentative and in need of more research. The classes of streams are:

Glacial
Lake-fed
Groundwater-fed
High relief, glacier-form watershed

Glacial streams.--Streams that originate from glaciers may be divided into three subtypes according to the presence or absence of accessory features such as glacial lakes and the contribution of melt water to the net flow. These subtypes are:

1. Glacial streams where melt water is the main source:

Samples taken by the U.S. Geological Survey indicate that suspended sediment concentrations in glacial streams are highly dependent on volume of melt water flow. Streamflow can, therefore, be used to estimate suspended sediment concentration. At high flows, concentrations may reach 200-600 ppm or more; and midrange flows may contain 20-100 ppm. Suspended sediment concentrations from November through April seldom exceed 20 ppm, because the amount of glacial melt water is lowest during that period. Glacial streambeds are probably "cleanest" in midspring to late spring just before glacial melt resumes.

Because of the youthful nature of watersheds of glacial origin, they usually contain landslide-prone mantle materials that may generate suspended sediment. The occurrence of fine-textured soils in these watersheds is highly variable depending upon occurrence of uplifted marine sediment or upon local sediment deposits. These watersheds do not contain ash deposits. Glacial sediments present during most high flows may mask the relative impact and conspicuous nature of sediments from other sources.

Little is known about the morphological characteristics of suspended sediment carried by glacial streams. The few analyses made of suspended sediment samples from these streams indicate that nearly all suspended material is less than 0.5 mm in diameter (coarse to medium sand) and that 75-95 percent is less than 0.25 mm (medium to fine sand).

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[1]Now the Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station.

2. Glacial streams with a lake catchment:

Thirteen suspended sediment samples from the Mendenhall River and Long River illustrate some characteristics of this stream type. These samples suggest that maximum sediment concentrations below lakes seldom exceed 300 ppm but do not drop as low as glacial streams without lakes. This is a logical consequence of greater temporary storage of fine sediment in the glacial lakes. It also follows that suspended sediments from this group of streams will be somewhat finer and will pass farther into the estuaries. Colloidal sediments will be similar in character to those of subtype 1 above. The description of sediment-producing soils as applied to subtype 1 also applies here.

3. Glacial streams with a small glacial influence:

This group of streams probably has the most variable intrastream suspended sediment concentrations. Like subtype 2, there are few samples available to represent this group of streams (21 samples). Yet, there are many streams that have a small but significant glacial influence. This group is very important.

There were no samples with concentrations greater than 170 ppm. Maximum concentrations have occurred from July through September and probably rarely exceeded 200 ppm. During winter seasons, concentrations drop to less than 10 ppm. Soils in these watersheds are more likely to produce sediment following roadbuilding or logging than most other soils. Landslide-prone soils often occur in these drainages. Landslides commonly occur toward the end of the glacial melt season, or shortly after the main part of the melt, when heavy rainfall and saturation of mantle materials occur.

Suspended landslide sediments contain organic material seldom found in glacial sediments and may be lower in specific gravity than fine glacial sediments. Consequently, these organic sediments do not settle as rapidly into the streambed as equally fine-grained glacial sediments. They will flush more rapidly from the surface of the streambed during high flow. Fine sediments from older soils may be more apt than glacial deposits to form aggregates or cementations when deposition occurs. The few suspended sediment samples from this group suggest that suspended material is less than 0.5 mm in diameter, with 60-95 percent less than 0.25 mm.

Ash soils provide a sediment hazard on Kruzof Island, northern Baranof Island, parts of southern Chichagof Island, and Revillagigedo Island; and the streams carry heavy bedloads. Though no significant measurements have been made in southeast Alaska, it is possible that the streambeds in this group are changed about every 5 years by bedload transport of streambed materials.

Lake-fed streams.--The criteria for streams of this group are that the watershed must be free from active glaciation and contain sufficient lake area to significantly influence surface runoff and storage characteristics.

Twelve streams in southeast Alaska for which suspended sediment data are available are in this group. One would expect lake-fed streams to have similar suspended sediment characteristics. Based on records for nine of the streams, there are uniformly low concentrations of less than 15 ppm during variable discharges. In contrast, however, three lake-fed streams, each located in very steep country, show high sediment concentrations. Concentrations up to 380 ppm

for a Takatz Creek sample and to 300 ppm for a Harding River sample have been recorded. In the case of Takatz Creek, suspended sediment may have come from a sizable tributary entering the creek below the lake outlet.

Deer Lake, about 40 miles south of Takatz Lake, shows a high concentration of 184 ppm. This sediment evidently comes from V-notches on the steep lakeside walls or from melt water of a remnant hanging glacier at the head of the lake; the sediment is probably nearly colloidal in size since larger sediments apparently settle out in the lake system.

Harding River, containing Fall Lake in its drainage, exhibits special noteworthy suspended sediment characteristics.

- A high "normal" range of suspended sediment for a lake stream (1 to 29 ppm), suggesting large supplies of frequently disturbed fine sediments.

- High concentrations during a spring flush-out period. This is not evident in any other stream of southeast Alaska that has been studied.

- No evidence of increase in suspended sediment with fall high flows.

The source for suspended sediment in Harding River drainage should be identified and understood so that this information can be applied to other mainland drainages. There are not sufficient suspended sediment particle analyses made to represent this group.

Landslide-prone soils are not as prevalent as in glacial stream watersheds. High-hazard, fine-textured soils often occur in these watersheds. Ash soil conditions occur near Sitka and on Revillagigedo Island.

Since these streams are below lake catchment basins, bedload supplies to the streams are often limited. The flows are usually more regulated and consequently do not move rapidly. These streambeds are vulnerable to the adverse effects of sedimentation.

Groundwater-fed streams.--Two streams of the Mendenhall Valley, Duck Creek and Jordan Creek, represent this group. The one set of samples for each creek shows 22 and 21 ppm suspended sediment. This small sample is insufficient for extrapolation to other groundwater systems. Furthermore, these two streams are high in iron, and one is badly polluted.

Managing the soils and streamside conditions of groundwater-fed stream systems may offer few problems as long as channels are not disturbed. These streams can carry only fine-sized particles, and their gradient can easily be upset by sediment in the channel.

High relief, glacier-form watershed streams (fig. 4).--This is the largest group of streams in terms of available sample information and is probably also the dominant stream system type in southeast Alaska.

From 16 streams sampled in this group, of 263 samples, 162 were from Hollis. At the time the Harris River watershed was being logged, two samples exceeded 100 ppm suspended sediments, and five other samples exceeded 50 ppm. Few of

Figure 4.--Punch Bowl Lake which drains into Rudyerd Bay.

the remaining samples exceeded 20 ppm, though Gold Creek at Juneau contained 230 ppm. The suspended sediment particle analysis from Gold Creek showed that, at high suspended sediment conditions, 99 percent of the suspended material was less than 0.5 mm and 96 percent less than 0.25 mm.

These streams often have landslides or slumps that enter directly into the stream channel and may produce torrents. This slump-slide action occurs in areas of till soils (example: Falls Creek near Thorne Bay) or ash soils (example: Kruzof Island soils).

The bedload of many of these streams is high, which limits the lasting influence of suspended sediment in the streambed.

SEDIMENTATION PROCESS

A general description of the sedimentation process in southeast Alaska streams will help evaluate the risk of sediment problems caused by man's activities. The discussion below describes sedimentation at various streamflow stages: during the rising stage, at peak flow, and during the falling stage. Some parts of this discussion are speculative in that the views expressed are not supported by measured observations. Other portions are based upon measured observations or samples. They are reasonable conclusions that attempt to tie together isolated measurements.

Virtually all of the gravel composition, bedload scour, and stream channel samples or observations are related to fish habitat research in riffles that are potential spawning areas. These were also areas accessible for sampling. A significant portion of each stream was thus eliminated from sampling and representation, with the sampled portions tending toward similar composition and bedload movement rate.

Rising stage.--On channel surfaces, sediment particles of fine sand size or smaller become suspended as turbulence increases. As flow rates and turbulence increase, material as large as coarse sand becomes suspended, removing more material from streambed surfaces. At the highest flows, materials as large as gravels move rapidly, and gravel and cobble material roll downstream. Streambed areas with flows that are constricted either by canyon walls, steep banks, or by debris in the channel will be frequently scoured. During periods of increasing flows, materials as large as cobbles will be swept downstream.

During this flow stage, the streambed form is altered to most efficiently handle both the flood flow and sediment load. Rising or high flows tend to produce scouring in upstream areas having steeper gradients--where earlier low flows have left sediment deposits--while favoring deposition in downstream locations having shallower gradients. In situations where rapid coastal uplift is accompanied by lowered sea level, either cutting or a reduced deposition rate will occur immediately above the area of tidal influence, and the stream's ability to carry bedload will be increased due to an increase in gradient near tide level. This situation is generally true north of Petersburg and to a greater extent on the west coast, as at Sitka, than on the mainland, e.g., near Juneau. There are other areas where the coastline may be subsiding, as on Kuiu Island. In these areas, stream profiles to tidewater are shortened, and the head of the tideland delta, in effect, moves upstream due to the rise in sea level resulting in a reduction in the sediment carrying capacity of the stream.

Peak flows.--During high flows, the entire streambed will be in motion to a variable depth. Depth of the moving bed will, of course, vary with the stream--some beds may be 6 to 12 inches deep over bedrock or marine sediments. Other streams of an active nature may have 2 feet or more of depth over a sub-bed deposit. Material suspended at peak flows moves at stream velocity, while larger material moves much more slowly along the bed. Some stream morphologists now contend that the mean annual flood is the event that has the most control on the form of the streambed, and presumably on streambed composition. Gravel sampling in southeast Alaska shows that many streambeds are regularly altered by stormflows, at least every 5 years.

Falling stage.--Material entering main streams as suspended load from steep tributaries may, in part, become bedload in main streams, particularly during the falling stage. Within stream channels, coarse material drops out first in pools and depressions. Successively finer materials settle into place as flows decrease. Part of the sands and other fines (small particles such as silts and clays) enter the streambed; another portion rests on or near the bed surface and remains in position for further moving or "flushing" downstream. Thus part of the sands and other fines are available as bed material to be "cleaned" from the streambed surface without requiring flow velocities that actually put the entire streambed in motion. Streams with high flows of short duration may be more limited in the volume of fine materials that are left on the bed surface during recession. On the other hand, streams with high flows of long duration may not only leave more fines on the bed, but may flush fines farther downstream during storms. The location and volume of deposited fine materials in or on streambeds thus become important in whether subsequent flows can clear the bed. The cleaning process depends upon periodic storm events that "plow" the bed and leave fine materials at the surface. This type of limitation to flushing exists if we assume that Vaux (1962) is correct in stating that fines, once in a streambed, cannot "flush out" unless the entire bed is in motion.

TEMPERATURE

It is well established that summer stream temperatures usually increase following the removal of streamside vegetation. Meehan et al. (1969) found that, following complete clearcutting of about 7 miles of main stream in Harris Creek and 5 miles of Maybeso Creek, temperatures rose an average of 7.2° C (4° F) and 16.2° C (9° F), respectively, during a single day.

The principal source of heat for stream water is direct solar radiation (Sheridan 1962, Brown 1969). When shade-producing streamside vegetation is removed, water temperatures may increase several degrees. The magnitude of increase depends on several other factors, too, such as volume of streamflow, ground water influences, length of channel exposed to solar radiation, and general climatic conditions. The most drastic changes are observed in small streams. Lakes and estuaries are affected more than streams (fig. 5).

Figure 5.--Chaik Bay on Admiralty Island with a typical intertidal zone and estuary.

Sheridan (1962) reported that stream temperature differences result from:

1. Geographic location of the stream
2. Size of watershed
3. Amount and type of precipitation falling on the watershed
4. Height of source region above sea level
5. Whether stream is lake fed or nonlake fed
6. Whether the watercourse is shaded or open

He concluded that the greatest temperature variation between streams occurred during the spring and summer. In the fall, stream temperatures from both cold and warm streams tend to show less differences, and the least variation occurs during winter and early spring when both cold and warm streams are nearly the same temperature.

Stream-water temperatures are especially important since they affect fish habitat. For example, pink and chum salmon do not utilize fresh water for rearing, only for spawning and incubation of eggs and alevins. Although some minor feeding may occur immediately following emergence, feeding and growth generally take place in the marine environment. Water temperature plays its main role in regulating the duration and timing of incubation, hatching, and emigration from the freshwater system. From the time of egg deposition and fertilization, a certain number of temperature units[2] are required for the eggs to develop into free-swimming fry. If this development is accelerated or delayed by even a very minor temperature increase, for example, 0.5° F, due to removal of streamside vegetation, fry may emerge considerably earlier or later than they normally would in that stream. Downstream migration to the sea might be impeded at that time, or conditions for growth and survival in the ocean might be unfavorable at that time of year. These are considerations that have largely been overlooked until recently.

In rearing areas, water temperature changes may affect habitat in different ways. Aquatic insects and other invertebrates which are food organisms may respond to temperature changes in terms of species composition as well as biomass. In some cases increased temperatures might be favorable. Cold streams shaded by dense forest canopies may not be optimum trout habitat (White and Brynildson 1967). Thinning riparian canopy would allow more solar energy to reach the stream, raising water temperature a few degrees and possibly increasing production of algae and aquatic insects.

Water temperatures can also affect growth rates and behavior of fish and other aquatic organisms. Metabolic rates and growth increase as temperatures rise.

In some situations where water temperatures were warm to begin with, an increase in temperature could contribute to decreased dissolved oxygen supplies and might promote the growth of slime bacteria or fungi which could cause excessive mortality of incubating eggs. Winter temperature change resulting from removal of insulating riparian vegetation is another area in which we lack definitive information. In southeast Alaska, where sustained periods of well-below-freezing air temperatures are common, a slight alteration of water temperature in winter might be more critical than summer increases.

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[2]A temperature unit (TU) is defined as 1° of temperature Fahrenheit above freezing for 24 hours; e.g., at 34° F constant temperature, eggs accumulate 2 TU's per day.

Salmon stream catalogs for southeast Alaska use 13° C (55.4° F) as a division between streams that are cool or warm during the spawning period. A few streams exceed 15° C (59° F) occasionally. For management purposes Bishop[3] proposed that streams be classified in one of four categories: (1) glacial, (2) cool, <10° C (50° F), (3) moderate, 10°-15.6° C (50°-60° F), and (4) warm, >15.6° C (60° F).

It is possible in some situations to predict with fair accuracy how stream temperatures will be affected by removal of streamside vegetation (Sheridan 1962, Brown 1969). Factors which influence this type of calculation include amount of streamflow, available radiation, surface area of stream exposed to solar energy, and length and time of travel of the stream through clearings. Confounding conditions include entry of surface water and ground water--the latter being the more complicated factor to deal with. Some study of volume of low summer flows should be done.

Streams that are considered sensitive to temperature changes have been identified on maps and in timber harvest guidelines. Recommendations include:

1. No more than 25 percent of streamside overstory canopy may be removed in the initial timber harvest entry.

2. When timber harvest occurs to the stream edge, a clearcut no longer than 1,320 feet on the cool side and 660 feet on the warm side may be made. This prevents extended stream exposure to the sun.[4]

Small streams that have extreme low flows are the most vulnerable to temperature increases following clearcutting. Studies now in progress show that stream temperatures rose for brief periods to critically high levels in some small streams that were clearcut to the streambank (see footnote 4). Other studies now in progress show that many of these small streams are critical rearing areas for some species of fish such as coho salmon and Dolly Varden char.

WATER CHEMISTRY

The water found in lakes, streams, oceans, and wells is never completely free of organic and inorganic matter. Water is a solvent and a mechanical erosive agent so it contains many dissolved minerals as well as those present as undissolved sediments in suspension.

The dissolved-solids content is often considered the most important criterion for assessing chemical quality, because suitability for drinking and industrial uses decreases as dissolved solids increase. (However, the reverse

[3]D. M. Bishop. A proposal for classification of streams of the Tongass Forest. Unpublished report in U.S. Forest Service files, Juneau, Alaska, 8 p., 1969.

[4]USDA Forest Service Environmental Statement, Ketchikan Pulp Company Timber Sale 1974-1979 Operating Period. On file at U.S. Forest Service, Juneau, Alaska.

relationship often applies for aquatic productivity.) Concentrations of dissolved solids may range from a few milligrams per liter (mg/l) in snowmelt or rainwater to over 35,000 mg/l in seawater. Freshwater as defined by Feulner et al. (1971) contains not more than 1,000 mg/l dissolved solids. Most Alaskan streams are freshwater, by this definition.

Water may be classified as fresh and still be unfit for many uses. The present standard for public water supplies recommends that the dissolved solids content not exceed 500 mg/l (U.S. Public Health Service 1962). Most industrial and municipal users prefer water with dissolved-solids content of 250 mg/l or less. Some Alaskan streams and much of the ground water contains more than 250 mg/l, so this factor may be important in selecting a source for municipal or industrial supplies, as well as for assessing the range of conditions for fish habitat quality.

Sampling from 38 points in southeast Alaska showed that dissolved-solids content ranged from 3 mg/l to 120 mg/l in the summer and from 1 to 105 mg/l in the winter. The average was 18 mg/l in the summer and 19 mg/l in the winter. Water in the northern portion generally had a higher dissolved-solids content than that in the southern portion. Surface water dissolved-solids content is generally of the calcium bicarbonate type with a few samples high in iron. All of the surface water samples were of acceptable quality by U.S. Public Health Service standards.

Often the most noticeable characteristic of water is its hardness. The ions of several metallic elements cause hardness, but those of calcium and magnesium are the most important. At one time, hardness was defined as a measure of the water's soap-consuming powers. Hardness also affects the tendency to form scale on heated metal surfaces such as boilers or tea kettles.

Stream-water hardness depends mainly on the kinds of bedrock exposed in the watershed. Streams draining granitic rocks contain soft water, whereas streams draining watersheds underlain by limestone are hard. Areas with high rainfall usually have streams with softer water than streams in areas with low rainfall. Ground water is usually harder than stream water in the same area (Feulner et al. 1971). The tabulation below defines hardness ranges.

Hardness range (mg/l of $CaCO_3$)[5]	Hardness description
0-60	Soft
61-120	Moderately hard
121-180	Hard
More than 180	Very hard

Water hardness may not be a critical consideration in developing domestic water supplies but is an important criterion in developing larger water systems for industrial uses.

The relative quantities of some of the ions affect the suitability of water for various uses. Many ions may be present in very small amounts without

[5]Milligrams per liter represents the weight of solute or sediment per unit volume of water.

affecting quality. Usually only a few are present in sufficient quantity to affect water quality appreciably. The four major cations are calcium, magnesium, sodium, and potassium. The four principal anions are bicarbonate, sulfate, chloride, and nitrate.

Ionic composition is important from the standpoint of drinking water quality. Sodium concentrations are usually not limiting, and potassium and bicarbonates are generally not limiting for most uses. Sulfate and chloride concentrations up to 250 mg/1 each are acceptable for most purposes, although water becomes corrosive and unpalatable at high concentrations.

Silica is the major un-ionized constituent in most water and a vital ingredient from a biological standpoint. Silica is necessary for the growth of diatoms which are organisms basic to the food chain. In some Alaskan water, silica is a limiting nutrient. Most Alaskan surface water seldom contains more than 10 mg/1 silica, but some streams contain as much as 30 mg/1. Ground water usually contains more silica than surface water. Silica concentrations from 30 to 60 mg/1 are common in ground water in some areas of Alaska.

Iron and manganese are a problem in water all over Alaska, particularly in ground water. Iron and manganese are often found in shallow wells but may be absent from deep wells in the same area. Iron probably causes more problems than any other constituent because it causes both scale and stains. Iron and manganese together should not exceed 0.3 mg/1 (U.S. Public Health Service 1962).

Information on the surface and ground water chemistry in Alaska is variable in coverage. Some regions have been periodically sampled for many years, and other areas are represented by only a few scattered samples. Although there is variation in chemical characteristics of the lakes and streams in Alaska, the ranges in concentrations are less than those found in the "lower 48" States. Most Alaska streams contain water of a calcium bicarbonate type usually containing less than 20 mg/1 dissolved solids. Streams in the lowlands usually contain harder water than streams in the mountains. Water in lakes is usually more variable in mineral content than river water. The water in some mountain lakes is very similar to rainwater in mineral concentration.

The water chemistry of lakes and streams may be affected by land use activities such as timber harvesting, roadbuilding, and mining. Gregory (1956) found that soil temperatures increased significantly following clearcut logging near Hollis on Prince of Wales Island. In addition to soil temperature changes, many nutrients in the soils and litter may be released following disturbance and by the soil warming caused by timber harvest.

In an area near Petersburg, Alaska, soils scientists sampled soil and creek water nutrient content before and after logging. Results are shown in table 2.

Such increases in nutrients can cause an increase in growth of algae, slime bacteria, and other indicators of stream eutrophication. This is unlikely to occur in free-flowing streams but occurs in streams with low gradient or obstructed flow, as well as in lakes and ponds. Associated with eutrophication and decomposing organic matter are reductions in dissolved oxygen content. Since a supply of oxygen is critical to all aquatic organisms, eutrophication as a result of human activity is unacceptable from a land-manager's viewpoint.

Table 2.--Nutrient content of soils and surface water before and after timber harvest[1]

Nutrient	Surface water (creeks)		Soil water: Tokeen Soils (well drained)		Soil water: Wadleigh Soils (somewhat poorly drained)	
	Timbered	Clearcut	Timbered	Clearcut	Timbered	Clearcut
	Milligrams per liter					
Nitrate	0.062	0.094*	0.055	0.116*	0.067	0.195*
Phosphate	.86	1.04	1.02	.914	.76	.915
Iron	.07	.15*	.1	.07	.1	1.30*
Calcium	1.72	1.45	1.30	2.23*	1.38	2.35*
Magnesium	.185	.24	.16	.34*	.20	.17
Potassium	.52	.85*	.35	.70*	1.68	2.65*
Sodium	1.12	1.16	1.60	2.26*	1.15	1.15
Organic carbon	4.8	6.3	7.0	12.5	7.0	30.0*

*Indicates that differences between samples from clearcut and timbered areas are probably real, judging by the magnitude of difference and variation between duplicate samples. Analysis by Federal Water Quality Laboratory, Fairbanks, Alaska.

[1]USDA Forest Service Environmental Statement, Ketchikan Pulp Company Timber Sale 1974-1979 Operating Period. On file, U.S. Forest Service, Juneau, Alaska.

The chemistry of surface water in Alaska may also be altered by the use of pesticides and fertilizers. Except for the use of herbicides on roadsides, there is no widespread use of either pesticides or fertilizers in Alaska yet; but modern land use practices include an increasing amount of insecticides, rodenticides, fungicides, herbicides, and other chemicals.

The storage and transportation of logs may also affect the chemistry of both freshwater and saltwater in Alaska environments. Bark and other debris, knocked off logs at dumping sites and in raft storage areas, forms a thick suffocating layer in subtidal and intertidal areas (Ellis 1970). Animals such as clams and crabs were scarce or absent at some dump sites that have been studied. Tidal currents in other dump sites prevented heavy bark accumulation.

Leachates also are released when logs are stored or transported in water. (These organic compounds, which are leached from all species of wood, condense and precipitate in seawater.) Pease (1974) found that high concentrations of leachates occurred at two log raft storage sites in southeast Alaska: Herring Cove near Sitka and Thorne Bay on Prince of Wales Island. Limited tidal flushing at Herring Cove resulted in continuous high leachate concentrations. Laboratory tests show leachate concentrations can be toxic to pink salmon fry. The density of benthic fauna was noticeably reduced in the vicinity of both active and inactive log dump sites.

Recommendations from Pease's study included:

1. Log bundles should not be unbanded in water unless sunken logs can be recovered.

2. Log bundles should not be stored in estuaries where they may be grounded at low tide.

3. Studies should be made of the feasibility of dredging bark deposits and removing bark from logs before dumping.

4. The benthic community of an area should be studied before dumping so that effects can be monitored.

Leachates also create a dissolved oxygen demand on the water during biodegradation and may lead to foaming problems (Schaumburg 1973).

Color-producing substances in the ligninlike leachates also reduce the esthetic quality of water and may make water unfit for drinking or recreation.

More studies need to be undertaken to provide additional criteria for designating dumping and raft storage sites in order to minimize possible environmental degradation caused by logging-associated debris and leachates.

WATERPOWER

Steep topography and heavy precipitation combine to provide many waterpower sites in southeast Alaska. From a waterpower standpoint, the region may be characterized as having small drainage basins, heavy runoff, high heads, and rather short runs to tidewater. Natural storage basins and accessibility to navigable waters combine to make the area potentially desirable for waterpower development. There are about 200 potential power sites which could produce an estimated 1,008,370 average horsepower (Federal Power Commission and U.S. Forest Service 1947).

The close relationship of potential waterpower and timber brought about a consolidation of efforts to inventory the waterpower resources. The Regional Forester of the U.S. Forest Service, Region 10, acted as the Alaska representative of the Federal Power Commission and a report was issued in 1947. The Federal Power Commission had issued a previous report called the "Dort Report" (1924) covering 50 waterpower sites. The engineers of the Federal Power Commission advocated an overall development so that many power sites could be combined to develop a large output of horsepower. Nothing was said of how this power would be used.

Waterpower has been and continues to be used in many places throughout Alaska to provide electricity for mining, sawmills, pulpmills, homes, and other uses. Large power installations such as the Snettisham project south of Juneau have recently been installed, and even larger projects have been proposed.

ESTHETICS

It is difficult to precisely define esthetic values of water. Many people in Alaska have never experienced polluted water. Many people in other parts of the world have experienced only water made safe by chemical additives. Esthetic values are related to the visual impact of water as well as the satisfaction derived from recreational use such as fishing, boating, and swimming.

Much of the water in the lakes, streams, ponds, marshes, and estuaries of Alaska still remains unaltered by man's activities. The rapid increase in population and resource development will almost certainly result in drastic changes to the land and water resources. Some of the more important activities that may affect water quality include mining, building dams and roads, logging, urbanization, and some forms of recreation.

It is not necessary to repeat the mistakes made during the development of the conterminous States. Much of the knowledge needed to protect the water and land resources is available. Technology has also advanced steadily in efficient ways to convert raw materials to manufactured products with little or no pollution.

The Wilderness Act of 1964, the Wild and Scenic Rivers legislation of 1968, and the Environmental Protection Act of 1971 all reflect a growing public concern for maintaining a high quality environment. Water is not only one of the more important resources that need to be maintained and protected, it is a requirement for life itself.

Some form of zoning or resource allocation is an important part of protection. The Alaska Department of Fish and Game has cooperated with the U.S. Forest Service in establishing an inventory of unique areas requiring special protection. This has been accomplished by correspondence and reviews of multiple-use plans.

Legislation is also an important part of maintaining water quality. The Alaska Department of Environmental Conservation (1973) has established regulations that will, if enforced, insure protection of the water resource.

When one views southeast Alaska with its thousands of miles of coastline, numerous fiords, bays, inlets, streams, and lakes, the word pristine comes to mind as a descriptive term (fig. 6). Maintaining pure water as a part of the pristine state is one of the most important challenges that land managers are confronted with today.

OUTLINE OF WATER RESEARCH NEEDS

Some of the research needed on water will overlap fisheries research needs. Water is also connected with recreation, wildlife, and esthetics. The more critical research needs are:

Figure 6.--Skowl Arm near old Kasaan on Prince of Wales Island.

1. Precipitation amounts, types, and patterns--Rain and snow intensity and duration pattern, effects of elevation and topography patterns (such as island orientation), interception by major vegetation communities.

2. Land and its cover--Effects of vegetation covers, timber harvesting, other land uses and patterns on streamflow regimen, production and quality, including the regulation of streams by watershed manipulation.

3. Soils--Soil moisture fluxes and their regulation in precipitation-runoff relationships.

4. Streamflow--Responses of regimen, quantity, and quality to precipitation, vegetation, and soil factors.

5. Stream channel development--Streambed geometry in relation to watershed characteristics; gravel morphology, composition, and stability as functions of stream characteristics and stream energy factors.

6. Dynamics of glaciers, icefields, and snowfields and the glaciohydrology of mainland streams--The response of streamflow and sedimentation to glacier nourishment, ablation, and climatological factors; glacier and icefield management for controlled water storage and release; factors affecting their development as a recreational resource.

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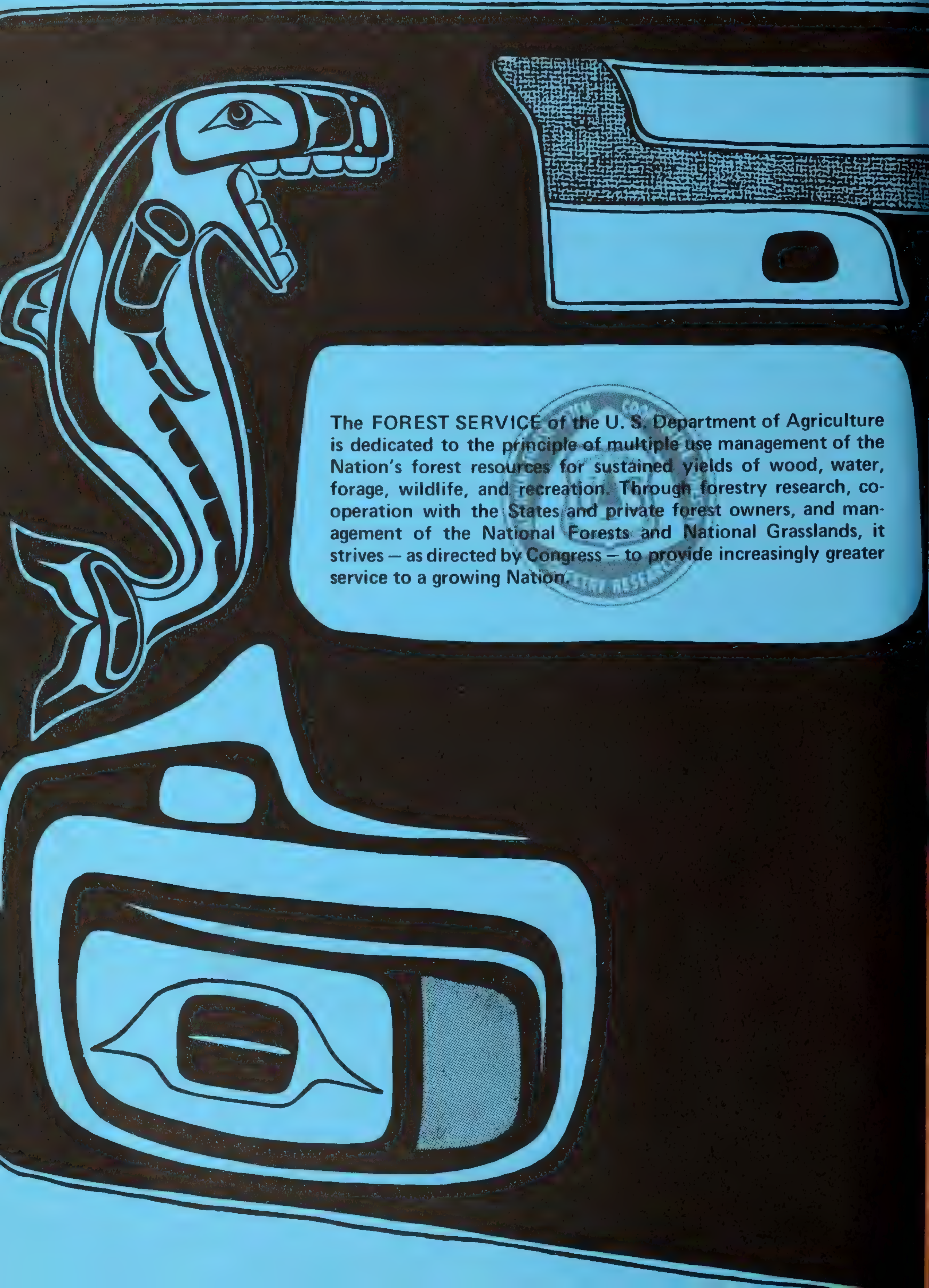

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1974
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STATUS of TIMBER UTILIZATION on the PACIFIC COAST

John B. Grantham

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Portland, Oregon

ABSTRACT

The need for additional sources of energy and raw material in the forest products industry enhances the opportunity to improve timber utilization by reducing logging residue. This is particularly true on the Pacific Coast where some 14 million tons of logging residue accumulate each year and where some 3 million tons of unused bark create a disposal problem at mills.

The need to replace natural gas and oil to generate process steam or for drying with hot gases has given impetus to improved wood and bark combustion to provide needed energy without violating air quality standards. Cylindrical furnaces burning finely ground (minus 1/8 inch) bark or wood are being installed for lumber and veneer drying. New emission control systems and predriers are being adapted to fire large furnaces with wood or bark.

The projected annual growth rate of 5 percent in U.S. and world pulp production has focused attention on forest residues as a source of fiber. Recent increases in chip prices help offset the high cost of logging residue, particularly if former disposal costs are credited to residue removal.

Changes in timber sale procedures to facilitate more complete timber utilization are considered essential. Such proposed changes as negotiated lump sum sales, service contracts, and compound contracts are described briefly to indicate types of sale modifications that have been proposed.

In summary, more complete timber utilization on the Pacific Coast may:

(1) Add substantially to the available raw material supply--8.4 million tons additional raw material annually.

(2) Add another energy source to that currently available as mill residue--4.0 million bone-dry tons for fuel annually.

(3) Protect thin soils by restricting or eliminating the amount of slash burning required.

(4) Decrease air pollution by reducing the required amount of slash burning.

(5) Reduce the debris that could interfere with streamflow and affect water quality.

(6) Improve scenic values by reducing visible debris.

(7) Improve recreational opportunities by providing easier access and a more acceptable environment.

(8) Reduce public criticism of land management policies and much of the basis for public pressure to restrict clearcutting.

KEYWORDS: Residues, logging residue, mill residue, timber utilization (- enterprise economics.

The use of trade, firm, or corporation names in this publication is not an official endorsement or approval by the U.S. Department of Agriculture of any product to the exclusion of others which may be suitable.

TABLE OF CONTENTS

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INTRODUCTION

Pressures are mounting for improved disposal of all residues, for greater national self-sufficiency in energy, and for more judicious use of our natural resources. These facts provide added incentives to improve timber utilization by reducing logging residue.

The Pacific Coast, in particular, has the need and the opportunity to emphasize more complete timber utilization. Here, harvesting the heavy stands of large, overmature timber on steep ground leaves immense quantities of wood and bark for subsequent disposal. Highly defective trees and steep, broken terrain can combine to produce heavy breakage and tremendous concentrations of debris.

This scenic region attracts a multitude of visitors, while its steepness increases the visibility of debris on cutover land. The combination tends to magnify the residue problem.

Fortunately, there are compensations. The Pacific Coast has major industries which depend largely or entirely on mill residue for raw material. The region's pulp industry obtains more than 85 percent of its raw material (11 million tons annually) from residue, and the board industry produces over 2 million tons annually of particleboard, insulation board, and hardboard entirely from mill residue. Both industries anticipate strong growth and will be seeking new raw material sources. Both, particularly the pulp industry, have the ability to effectively use substantial quantities of residue for energy production.

An overview of harvested timber flow on the Pacific Coast is given in figure 1 and table 1. The recent upturn in world pulp and paper demand and the strength of the domestic particleboard market are having a favorable effect on mill residue use but have had less impact on logging residue.

It is the aim of this paper to indicate the quantities and characteristics of logging and unused mill residues on the Pacific Coast and to point out changes or opportunities for more complete use of the forest resource. Because of the relatively greater quantities and problems associated with logging residue, the main emphasis will be on that material rather than on mill residue.

The report is directed primarily to those who are concerned with reducing logging residue to improve forest land management--and to supply added raw material in the process.

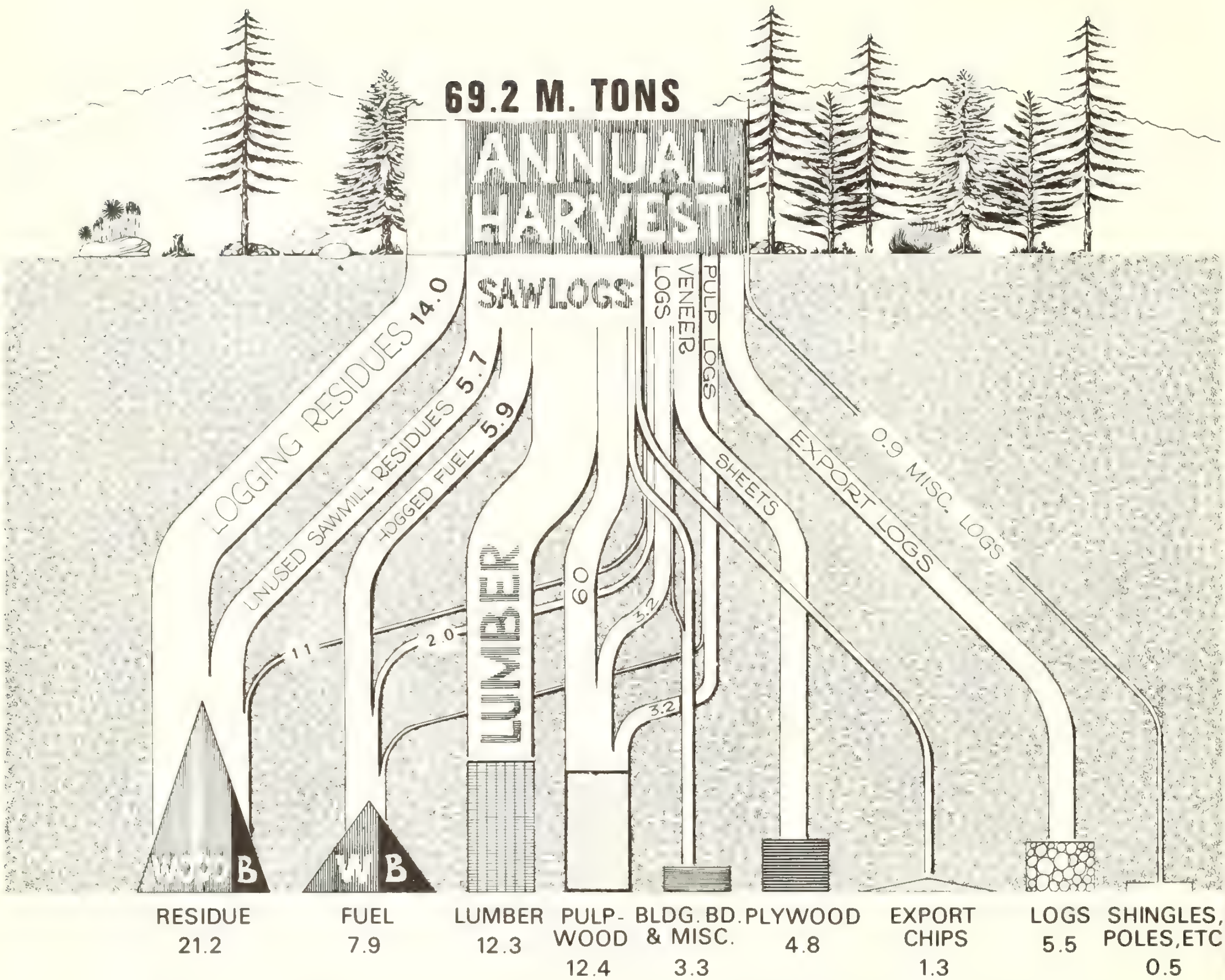

Figure 1.--Disposition of the timber harvest on the Pacific Coast in millions of bone-dry tons, 1968. Residue and fuel include wood and bark. Residue also includes 0.4 million tons of unused residue from manufacture of shingles, pilings, etc.

Table 1.--*Approximate material balance for Pacific Coast log production, 1968*

(Millions of bone-dry tons)

Item	Weight
Log production[1]	55.14
Apparent log use	
Lumber	33.44
Veneer	12.10
Export	5.47
Pulp	3.22
Shakes and shingles	.71
Poles and piling	.19
Total	55.13
Output from lumber and veneer logs	
Lumber[2]	12.25
Plywood[3]	4.78
Pulp chips, etc., from residue	13.70
Fuel from residue	7.90
Unused mill residue	[4] 6.90
Total	45.53

[1] Logs are estimated to weigh 2.5 tons per thousand board feet, net Scribner scale, including defective wood and bark.

[2] Finished lumber is estimated to average 0.75 bone-dry ton per thousand board feet, lumber tally.

[3] Plywood 3/8 inch thick is estimated to weigh 0.425 bone-dry ton (exclusive of glue) per thousand square feet.

[4] Another 0.4 million tons of residue was developed in the manufacture of shingles, shakes, poles, and piling.

QUANTITIES AND CHARACTERISTICS OF WOOD RESIDUE AVAILABLE

Mill Residue

Detailed studies of mill residue development and disposition in California (Barrette et al. n.d.), Oregon (Manock et al. 1970), and Washington (Bergvall and Gedney 1970) have been made for the year 1968. Findings of these studies were used to summarize the types and quantities of unused mill residues available on the Pacific Coast in 1968 (table 2) and to reveal the overall disposition of mill residues in the region during that year (table 3). Since the general situation concerning log, lumber, and plywood production on the Pacific Coast remains rather stable, the 1968 illustration of wood flow in the region is still appropriate except for the substantial increase in mill residue use.

Table 2.--*Characterization of unused mill residue on the Pacific Coast, 1968*

(Thousands of bone-dry tons)

Location and industry source	Wood			Bark
	Coarse[1/]	Medium[2/]	Fine[3/]	
California[4/]				
Veneer and plywood	73	--	6	113
Lumber	823	309	787	1,053
Other	--	--	[5/]3	1
Oregon[6/]				
Veneer and plywood	244	--	35	434
Lumber	463	176	602	908
Shake and shingle	28	--	60	40
Washington[7/]				
Veneer and plywood	89	--	4	104
Lumber	135	91	171	232
Shake and shingle	69	--	125	94
Total	1,924	576	1,793	2,979

1/ Veneer trim, cores, and panel trim from plywood plants; slabs, edgings, and trim from sawmills.

2/ Planer shavings.

3/ Sanderdust from plywood plants; sawdust.

4/ From Barrette et al. (n.d.).

5/ Source and class of residue not specified.

6/ From Manock et al. (1970).

7/ From Bergvall and Gedney (1970).

Table 3.--*Disposition of mill residue produced on the Pacific Coast, 1968*[1]

Disposition	Millions of bone-dry tons
Residue to pulp production:	
To export pulp chips	[2] 1.3
To domestic pulp from sawmills	6.0
To domestic pulp from plywood production	3.2
Total	10.5
Residue to building board production:	
From sawmills	1.4
From plywood production	.3
Total	1.7
Residue to fuel:	
From and at sawmills	5.9
From and at veneer and plywood plants	2.0
Total	7.9
Residue to miscellaneous use:	
Total	1.6
Residue unused:	
Wood	4.3
Bark	3.0
Total	7.3
All mill residues	[3] 29.0

[1] From Barrette et al. (n.d.), Manock et al. (1970), Bergvall and Gedney (1970).

[2] From Holt (1973).

[3] Includes 0.4 million tons of residue from shingle, shake, pole, and piling production.

Estimates of residue use for building board, domestic pulp, and export pulp chips during the period 1968-72 (table 4) indicate that all unused wood residue developed in primary manufacturing as recently as 1968 should have found an outlet. The picture, however, is clouded by the glut of mill residue that occurred during the period of high lumber and plywood prices in 1972-73--when processing of low-grade logs resulted in excessive quantities of mill residue. Also, pulp chips from British Columbia are available by barge to pulpmills on Puget Sound and at least one firm brings in chips from Idaho.

Many sawmills and veneer plants of the region have a bark disposal problem, and because of location, some have a sawdust disposal problem, even though all chippable wood is salable. Tighter air quality standards and increasing restrictions on land fills add to the severity of disposal problems. Thus, although this analysis emphasizes ways to encourage and facilitate the use of logging residue, there is a continuing need to find outlets for unused mill residue at remote locations.

Table 4.--*Consumption of residue for domestic pulp and building board production and for export chips, Pacific Coast, 1968-72*

(Thousands of bone-dry tons)

Year	Residue consumed			
	Domestic pulp[1/]	Building boards[2/]	Export chips[3/]	Total
1968	9,202	1,685	1,292	12,255
1969	9,548	1,890	1,704	13,142
1970	10,058	2,277	2,111	14,446
1971	10,361	2,024	2,229	14,614
1972	11,093	2,594	2,523	16,210

1/ 1968--Barrette et al. (n.d.); Manock et al. (1970); Bergvall and Gedney (1970). 1969-72--Derived from data of Census of Manufactures, U.S. Bureau of Census, through American Pulpwood Association.

2/ Annual Board Review issues (July) of *Forest Industries*, using following board production to wood consumption factors:

1/2-inch insulation board $\frac{\text{M ft}^2}{2.667}$ = M bone-dry tons

1/8-inch hardboard $\frac{\text{M ft}^2}{2.917}$ = M bone-dry tons

3/4-inch particleboard $\frac{\text{M ft}^2}{0.667}$ = M bone-dry tons

3/ From Holt (1973).

Logging Residue

Logging residue, which accumulates on the Pacific Coast at a rate of about 14 million tons (gross) annually, has found little sustained use because of its scattered origin and the cost of delivering it to a point of use.

In describing the logging residue that accumulated in 1969, Howard (1973) states that 10-1/2 million tons (about three-quarters of the total) is sound, chippable wood. Concentrations of residue varied from an average of nearly 57 tons per acre in the Douglas-fir region of western Oregon and Washington to as little as 4 tons per acre in the ponderosa pine region of the two States (table 5).

The logging residue accumulated annually in the Douglas-fir region (western Oregon and Washington) amounts to more than half of the total accumulation on the Pacific Coast. In the Douglas-fir region, too, 70 to 80 percent of the sound, chippable

Table 5.--*Average net and gross weight of logging residue,*[1/] *by ownership and region, Pacific Coast, 1969*
(Bone-dry tons per acre)[2/]

Region and ownership	Gross weight	Net weight[3/]
Oregon and Washington		
Douglas-fir region:		
National Forest	57	39
Other public	33	25
Private	19	17
Ponderosa pine region:		
National Forest or private[4/]	5	4
California		
National Forest[4/]	18	15
Private	24	17

1/ Pieces at least 4 inches in diameter and 4 feet long.

2/ Derived from Howard (1973), using an average of 25 pounds per cubic foot as the bone-dry weight of residue.

3/ Includes sound portions of all pieces with at least 10 percent of gross volume suitable for pulp chips.

4/ Includes "other public."

wood is in pieces 8 inches and larger in diameter and 8 feet or longer. Further, about half of the chippable volume is in utility (pulp) logs.[1/] The weight of chippable wood left on clearcut lands in the Douglas-fir region varies with the minimum diameter and length of pieces considered (table 6). For minimum dimensions of 8 inches in diameter and 8 feet in length, the chippable wood amounts to 0.6 bone-dry ton for each thousand board feet of logs harvested.[2/] For the Pacific Coast as a whole, there is 0.5 bone-dry ton of chippable wood residue per thousand board feet logged.

The scattered origin of logging residue and its varying size and shape as compared with merchantable logs combine to bring the average per-ton cost of logging residue above $30, delivered to point of use. By comparison, mill residue has been available at costs of about $2.50, $10, and $20 per dry ton for hogged fuel, planer shavings, and pulp chips, respectively, delivered to a major center of use.

1/ A utility log has a minimum diameter of 6 inches, a minimum length of 12 feet, and contains at least 50 percent of its volume in sound, chippable wood.

2/ The corresponding gross weight of residue, including bark, is estimated to be 0.9 bone-dry ton per thousand board feet. The difference would be available for fuel, if all residue were brought out of the woods.

Table 6.--*Relationship of residue weight to log volume harvested on National Forest clearcuts of the Douglas-fir region in 1969*[1/]

(Bone-dry tons of residue per thousand board feet of logs harvested)

Minimum diameter	Minimum length		
	8 feet	12 feet	20 feet
	Gross weight of residue[2/]		
4 inches	0.95	0.77	0.44
8 inches	.90	.73	.42
12 inches	.80	.64	.38
	Net weight of residue suitable for chips		
4 inches	0.65	0.52	0.29
8 inches	.60	.49	.27
12 inches	.50	.40	.23

1/ Derived from Howard (1973), using an average of 25 pounds per cubic foot as the bone-dry weight of residue.

2/ Does not include bark, estimated to add 10 percent.

Costs in the two classes of residue differ because the slabs, edgings, veneer cores, sawdust, etc., are not developed until primary processing occurs; therefore, the cost of transporting this material to the sawmill or veneer plant is borne by the primary product. In contrast, tops, slabs, cull log sections, broken chunks, etc., can be separated from the merchantable portions of trees in the woods. Once separated, they bear the full cost of collection and transportation to point of use. The per-ton costs of delivering merchantable and nonmerchantable wood from stump to plant are estimated in table 7; costs are based on some broad assumptions of current logging costs, since they vary so widely with time and conditions.

Table 7.--*Costs of delivering wood to forest industry plants under certain assumptions*

(Dollars)

Cost item	Assumed cost per thousand board feet, net log scale	Assumed costs per bone-dry ton		
		Merchantable logs[1/]	Utility logs	Other residue[2/]
Stumpage	--	Full charge	Nominal charge	No charge
Road construction	12.00	4.80	--	--
Road maintenance	2.50	1.00	1.00	1.00
Fall and buck	6.00	2.40	2.00	.50
Yard	9.00	3.60	7.50	10.50
Load	3.00	1.20	1.20	1.50
General expense including overhead, depreciation, etc.	8.00	3.20	3.20	3.20
Total	40.50	16.20	14.90	16.70
Haul, 40 miles[3/]	14.00	5.60	5.60	6.00
Preprocess:				
Debark	--	1.50	--	--
Sort, debark, chip	--	--	3.50	7.00
Total	54.50	23.30	24.00	29.70

1/ Merchantable logs are assumed to weigh 2.25 tons per thousand board feet, gross, or 2.50 tons per thousand board feet, net, Scribner Decimal C scale.

2/ To 8-inch diameter, 8-foot length, minimum dimensions.

3/ Based on 3 round trips in 11-1/2 hours with loads averaging 5,000 board feet.

The decision to separate standard (merchantable) from substandard material in the woods is increasingly difficult. Application of the marginal log concept[3] is being challenged by the need to view the complete land management job and then decide the best harvesting practice to accomplish that job. Physical, environmental, silvicultural, and economic criteria should be considered in determining the best logging method.

There is growing sentiment to remove everything over a certain minimum size and later sort the logs for conversion to lumber, veneer, pulp, board, poles, fuel, etc. Within this concept, much of the former logging residue is removed as utility logs, and logging residue is limited largely to branches, tops, or completely defective material that may be well crushed and scattered by the close utilization. Some minimum size, such as 5 cubic feet or 30 board feet (10 inches x 10 feet; 9 inches x 12 feet; 6 inches x 24 feet),[4] would be set up as a requirement for removal.

The changes in energy and raw material needs, particularly the projected increases in domestic and worldwide pulpwood requirements,[5] give potential value to nearly all timber resources. It is appropriate, therefore, to consider ways of achieving more complete use of timber resource immediately.

WOOD RESIDUE USE ON THE PACIFIC COAST

As Raw Material

Nationally, domestic pulpwood use in 1970 was 4 billion cubic feet of roundwood (over 50 million bone-dry tons) and 1.6 billion cubic feet (20 million bone-dry tons) of mill residue (table 8). Use of mill residue is expected to increase significantly, to 35 million tons by 2000, but the use of roundwood, which may include logging residue as well as thinnings, salvage cuttings, and some sawtimber, is expected to increase dramatically to nearly 115 million tons.

On the Pacific Coast, mill residue already provides more than 85 percent of the pulp industry's raw material and between 15 and 20 percent of its energy needs. The quantity supplied by pulp logs was rather constant during the period 1961-70 but dropped sharply in 1971 and 1972 (fig. 2). Meanwhile, mill residue has supplied all of the material needed for the industry's growth of about 4.3 percent per year during the 1960's. Recent increases in mill residue use are detailed in table 4.

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[3] The marginal log may be most easily defined as the log which an operator would like to leave, if he could. Stated another way, a logger works to maximize net return per day or season. He, therefore, concentrates on the higher grade and larger logs. He may leave low value or small logs on one area, if he can move to another sale area where higher grade logs are available.

[4] It is practical to run smaller material through whole tree chippers where the terrain permits their use, but this does not apply generally to those areas on the Pacific Coast where the heaviest concentrations of residue occur. Where the condition of the timber and the steepness of ground combine to create heavy residue (100 tons per acre or more), it may be necessary to burn the fine material remaining after recovery of the larger residue. However, the resulting fire should be less damaging to the site.

[5] John R. McGuire. Meeting prospective timber demands. Paper presented to North Carolina Pulp & Paper Foundation, Raleigh, N.C., Nov. 1973.

Table 8.--*Domestic roundwood and mill residue consumption in the United States in 1970 compared with projected consumption in 2000*[1/] [2/]

(Millions of cubic feet)

Product group	Reported 1970 consumption		Projected 2000 consumption	
	Roundwood	Residue[3/]	Roundwood	Residue[3/]
Saw logs	6,100	--	7,600	--
Veneer logs	1,200	--	2,000	--
Pulpwood	4,000	1,600	9,100	2,800
Miscellaneous products[4/]	400	600	400	1,200
Fuelwood	500	700	500	700
Total	[5/]12,200	2,900	19,600	4,700

[1/] Based on medium level of projected demand and prices 10 to 30 percent above 1970 levels.

[2/] From USDA Forest Service (1973, tables 149 and 150).

[3/] Residue developed in converting roundwood to such primary products as lumber and plywood. It is used chiefly for pulp, particleboard, and fuel.

[4/] Includes roundwood for cooperage, poles, piling, mine timbers, shingles, and some board products; it also includes the residue used primarily for building boards.

[5/] The totals include an estimated 7,900 (1970) and 10,400 (2000) million cubic feet of sawtimber. The balance in each case is roundwood from such sources as cull and dead trees, trees less than 5.0 inches in diameter, and hopefully will include much logging residue.

In 1972, both the pulp and the board industries on the Pacific Coast anticipated that their annual raw material needs would increase by 1 million tons and 1.8 million tons, respectively, by 1980 (Austin 1973). Both expected that the modest increase in raw material needs could be supplied entirely by mill residue. However, the burgeoning markets for paper and board that now prevail worldwide require that both industries include logging residue in their raw material plans.

An annual growth rate of 5 percent is now forecast for the pulp industries of both the United States and Japan; the particleboard industry is expected to grow even more rapidly. As indicated previously, all chippable wood residue available at Pacific Coast mills will soon be committed. Thus, the 10-1/2 million tons of chippable logging residue accumulating annually on the Pacific Coast deserves increased attention.

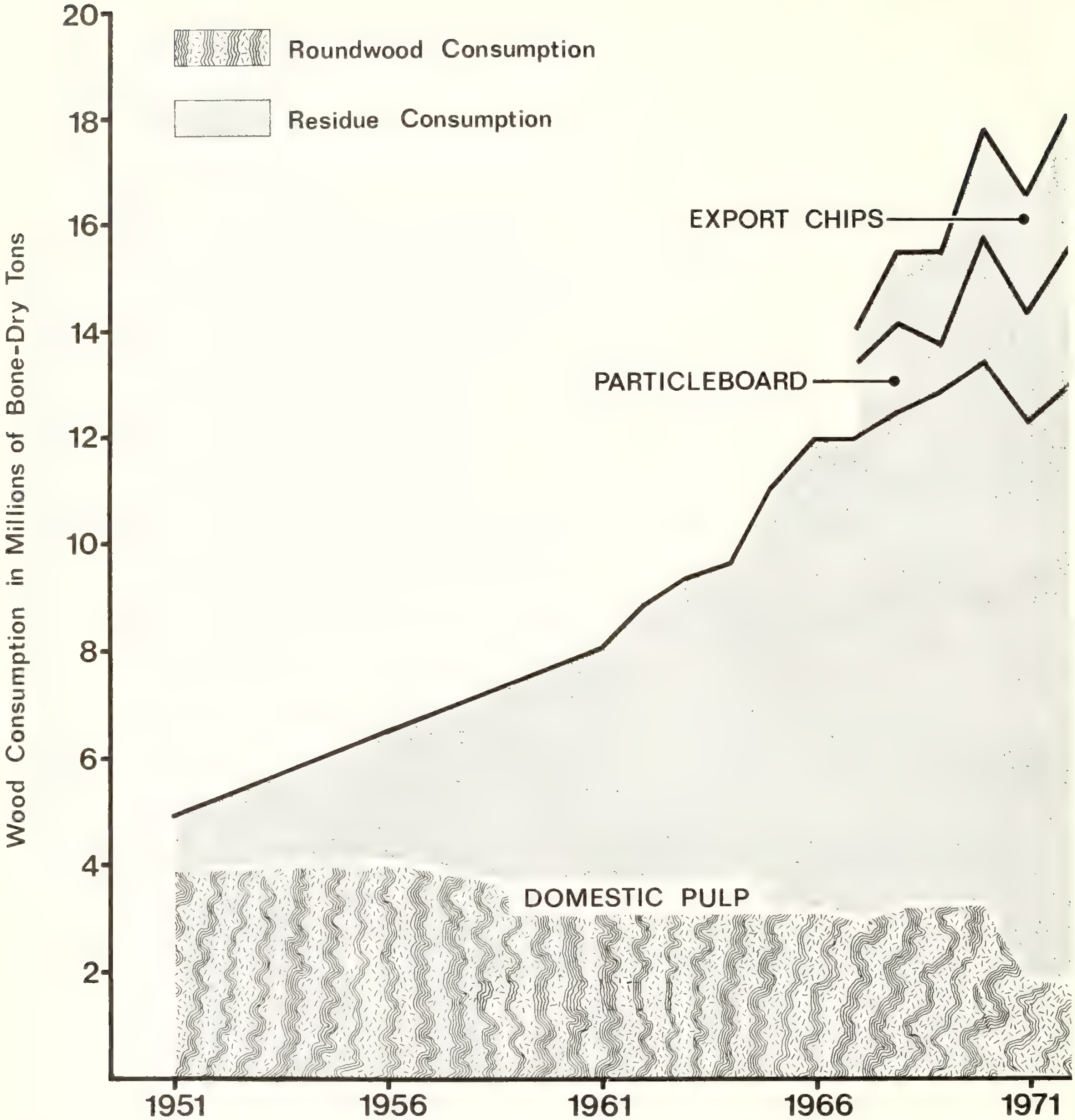

Figure 2.--Trends in the consumption of roundwood and mill residue on the Pacific Coast by the pulp and particleboard industries. (Sources are those shown in table 4, plus Northwest Pulp and Paper Association 1973.)

As Fuel

The Pacific Coast, along with other parts of the United States, suffers increasing power deficits as growing demand outstrips new sources. The potential contribution of wood and bark residue to the energy crisis is substantial but not so great as that of coal. For example, the total annual timber harvest in the United States is less than half the domestic production of coal on a dry weight basis. Wood's greatest contribution to satisfying domestic energy needs could be made through expanded use of wood and bark residue as a replacement fuel for oil or gas in forest industry plants--particularly in pulp plants where energy needs are so great. Wood residue can best be used for energy at forest industry plants because these plants:

(1) Have facilities for transporting and handling wood.
(2) Can use residue as raw material or fuel and thereby increase its average value.
(3) Can use steam to generate power and then use the remaining heat in drying or other processing. This can double thermal efficiency.
(4) Can use residue at many locations and avoid additional transportation costs needed to concentrate residues at central points.

In 1968, the Nation's pulp industry used 2 percent of the Nation's total purchased energy of 60,500 trillion Btu's (table 9). These purchases of fossil fuels and electricity amounted to 6 percent of the Nation's industrial demand.[6/] Energy recovered from burning spent cooking liquor to recover chemicals and that recovered by burning the

[6/] Ronald J. Slinn. Sources and utilization of energy in the U.S. pulp and paper industry. American Paper Institute, New York, Mar. 1973.

Table 9.--*Energy consumption in the United States, 1968*[1/]

(Trillions of Btu's)

Sector	Coal	Natural gas	Petroleum products	Hydro and nuclear power	Subtotal	Purchased electricity
Residential		4,600	3,200		7,800	1,400
Commercial	600	1,800	3,400		5,800	1,100
Industrial	5,600	9,300	4,500		19,400	2,000
Transportation		600	14,500		15,100	0
Electric utility	7,100	3,200	1,200	900	12,400	(-4,500)
Total	13,300	19,500	26,800	900	60,500	0

[1/] Adapted from Stanford Research Institute (1972). From the reported average annual growth rate of 4.5 percent, consumption of 69,000 trillion Btu's was predicted for 1971.

bark received with pulpwood provides 37 percent of the industry's energy requirements. The industry is giving serious study to reducing energy requirements in pulping, bleaching, and drying. Major effort is being given to reducing water use by operating at higher consistencies and in a more nearly closed system. However, reduced water use creates numerous side problems that require solution. Meanwhile, stricter standards of air quality in an unbleached kraft mill require 13-15 percent more energy and may require an equivalent increase in the future.[7/]

The pulp industry's vast energy requirements are summarized by source in table 10. The gas and oil used in 1971 were equivalent to 160 million barrels of oil at 6.3 million Btu's per barrel. To replace this 160-million-barrel equivalent would require 80 million tons of hogged fuel at the commonly used ratio of 2 barrels of oil per ton, but even partial replacement will help reduce oil demand.

The heat value of hogged fuel varies with its composition and its moisture content. In general, good hogged fuel should produce 11,000 pounds of steam per unit,[8/] whereas poor (extremely wet) hogged fuel should produce about 9,000 pounds of steam per unit. Stated another way, one unit of hogged fuel will produce 8 to 10.5 million Btu's in older boiler installations or up to 12.5 million Btu's in modern boiler installations. A rule of thumb is that a unit of hogged fuel will produce 10,000 pounds of steam or 10 million Btu's. A unit of wood which produces 10 million Btu's is roughly equivalent to 2 barrels of oil (6.3 million Btu's per barrel) when the oil is burned at average efficiency of 80 percent.

Unfortunately, it was easier and less costly for forest industry plants to change from hogged fuel to gas or oil some 25 years ago than it is now to revert to solid fuel with attendant higher furnace costs and more cumbersome fuel storage and handling. However, growing scarcities of natural gas and low-sulfur oil threaten production losses and strongly favor residue-fired power boilers.

Increased emphasis on wood residue burning should lead to improvements in fuel handling, combustion efficiency, and emission control. Predrying fuel to give greater furnace capacity also helps reduce the high investment cost in residue-fired furnaces. Technological progress in residue use for fuel is considered later in this report.

Possibilities of producing methanol, methane, oil, or other versatile fuels from forest residue are not discussed, because these would be produced in large plants outside the forest industry. Considering that coal, lignite, or a variety of organic wastes are also suitable raw materials and considering the huge capacities proposed for methanol plants, for example, it is unlikely that forest residues will be so used. Instead, wood and bark are considered too valuable to the forest industry for raw material or fuel.

[7/] James E. Roberson. Energy and air emissions in the pulp and paper industry 1973. Talk at the University of Wisconsin Extension Division short course, "Energy and the Pulp and Paper Industry," Milwaukee, Wis., Oct. 1973.

[8/] The unit applied to bulk measurement of fine wood residue such as hogged fuel or sawdust is the quantity occupying 200 cubic feet of bulk volume. The bone-dry weight of a unit will vary with compaction and species density but, for this report, is considered to be roughly equivalent to 1 ton. A bone-dry unit of pulp chips generally is considered to be equivalent to 2,400 pounds, based on Douglas-fir and high compaction.

Table 10.--*Energy sources in U.S. pulp and paper manufacture, 1971*

Source	Energy equivalent	Percent of total
	Trillions of Btu's	
Spent cooking liquor (recovery furnace)	667	28.5
Bark and wood (power furnace)	197	8.5
Natural gas (power furnace)	569	24.0
Oil (power furnace)	440	19.0
Coal (power furnace)	374	16.0
Purchased electricity[1/]	94	4.0
Total energy[2/]	2,341	100.0

1/ Equivalent to 27.6 billion kWh at 3,413 Btu/kWh.

2/ Equivalent to nearly 43 million Btu's of energy per ton of paper produced (or 27 million Btu's of purchased energy, which amounts to about 2 percent of the U.S. total).

PROGRESS TOWARD MORE COMPLETE TIMBER UTILIZATION

Diversified Outlets for Residue

The continuously increasing use of wood residue on the Pacific Coast (table 4) and projected demand for wood raw material by 2000 (table 8) improve the opportunity to use logging residue as a raw material source. The need for new energy sources and the pulp industry's high energy requirements (table 10) provide a valuable outlet for that portion of logging residue that is unsuited for products. For illustration, a million tons of logging residue might yield 300,000 tons of logs, blocks, or cants for lumber and veneer production, 500,000 tons of chips for pulp or particleboard, 200,000 tons of wood fines, and 100,000 tons of bark. Bark, amounting to about 10 percent of the wood residue weight, is not included in estimates of residue quantities and represents an added source of energy.

There is a need for log sorting or segregation yards, complete with some sawing or log-breakdown equipment and chipping facilities. Saw logs or portions of cull logs suitable for lumber or veneer could be diverted to such relatively high value use; whereas chips, hogged fuel, bark mulch, etc., produced at the sorting center could be sold or transshipped for final processing and marketing. Log sorting will be discussed more fully in "Development of Log Sorting Centers."

The diversified uses of residue emphasize the fact that the focus should be on complete timber utilization rather than residue recovery. In complete timber utilization, the entire timber stand is used to the best possible advantage at that time and place. The schedule of payment for services and the bid offer for merchantable timber produced will reflect in part the optional uses of the complete stand that are available to the contractor. Where one area has limited use opportunities, some provision for public help to provide additional facilities may be considered.

Advances in Materials Handling

Advances in materials handling that should help reduce logging residue are forecast by Lysons and Twito (1973) and amplified by Lysons (1974). The authors point out the importance of defining any timber harvesting problem in terms of timber size and condition, ground profile, cutting treatment, residue handling, environmental requirements, and access to the area. Constraints such as the availability of skilled manpower, capital, markets, and fuels must also be considered. Once the problem is defined in terms of specific needs and applicable constraints, there is a sounder basis for deciding the logging method.

SELECTING THE YARDING SYSTEM

Selecting the yarding method that best meets the requirements and constraints of a specific timber sale will benefit both the logger and the land manager: the logger by more favorable costs, the land manager by easier contract administration. For example, if it is necessary to clean log a defective, overmature stand on steep ground, grapple yarding with a running skyline may be the best system (fig. 3).

Grapple yarding.--Grapple yarding which uses remotely controlled grapples in place of hand-set chokers to move logs or chunks from stump to road is often more suitable than conventional systems to log difficult settings. As practiced to date, grapple yarding generally has been limited by machine characteristics to short distance, but good interlock drum systems are overcoming this limitation. Lysons (1974) envisions yarding distances up to 1,500 feet with grapples on a running skyline. Mobility of the yarder will be facilitated by a tractor-mounted tail spar moving along a perimeter firebreak. Logs would be windrowed for later loading unless some intermediate transfer were required because of the number of pieces yarded at one machine setting.

Grapples cannot be used in high-lead yarding because the system does not provide an operating line to control the grapples.

The adoption of grapple yarders, especially those with a good interlocking drum system, will be hastened by the great economy of the system. Operator experience with grapple yarding indicates higher production and lower daily cost (because of small crew size). Production in grapple yarding may be 100 pieces per day greater, and the cost $200 per day less, than for high-lead yarding. The difference in yarding cost is particularly important with small pieces (fig. 4).

Although grapple yarders require high capital investment, they are often worked two shifts to reduce capital costs and payout periods.

Figure 3.--Grapple used for yarding on Vancouver Island.

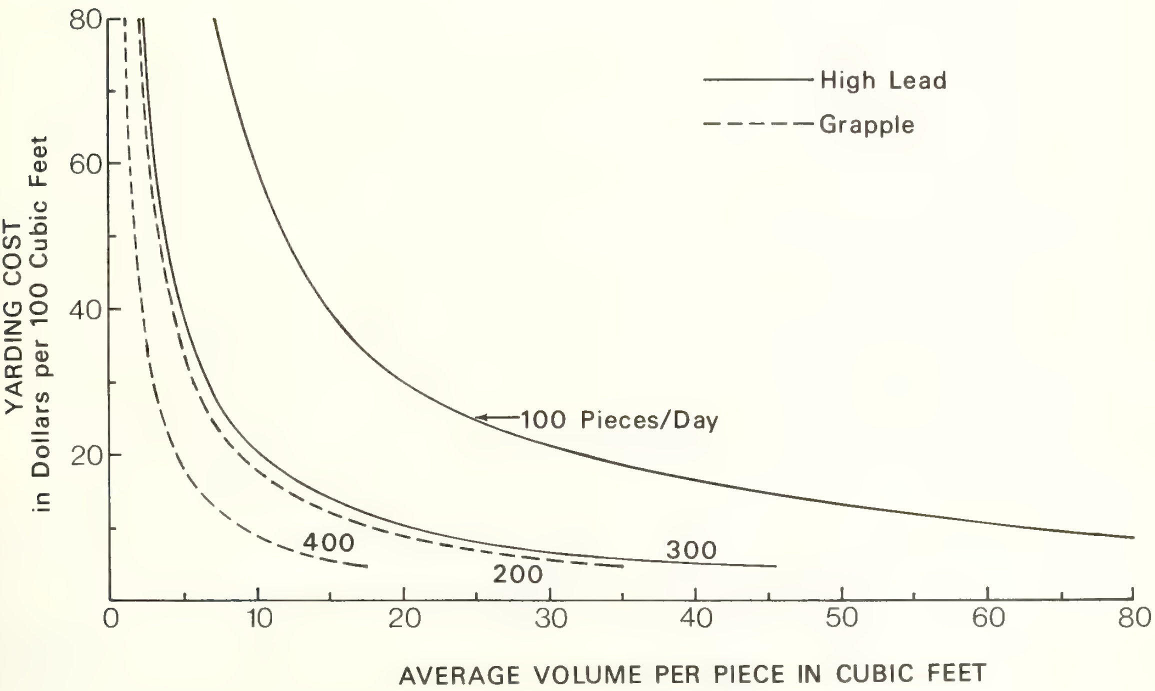

Figure 4.--Relationship of yarding costs to volume per piece for high-lead and grapple yarding at two assumed rates of production. High-lead yarding (daily cost $600 for equipment and labor) at 100 and 300 pieces per day. Grapple yarding (daily cost $350 for equipment and labor) at 200 and 400 pieces per day.

The added sorting required by the greater mix of logs produced in clean logging could be simplified in the woods by use of a grapple skidder to transfer logs from the landing to a nearby sorting-loading point. This would also have the advantage of divorcing the loading operation somewhat from the yarding operation. Developments in grapple loaders provide additional gains in residue handling as, once a bunk load is built, the grapples can pick up one or several pieces depending upon their size and arrangement (fig. 5).

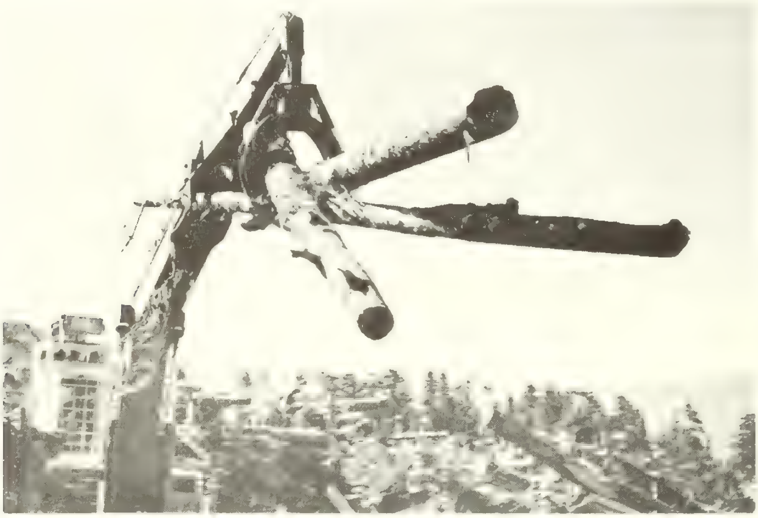

Figure 5.--Grapple loader at work on Vancouver Island.

Other considerations.--One operator is considering two-stage logging as an alternative to clean logging--with initial logging taking all pieces over a given size regardless of quality. Secondary yarding would be conducted later by a different crew or by a subcontractor using lighter equipment. The operator believes this may help overcome the aversion of production-minded loggers to handling small-diameter material. At the same time, it leaves responsibility for the complete job with the primary logger.

FALLING AND BUCKING PRACTICES

A serious limitation to the recovery of logging residue has been the short length of the pieces. Short lengths not only reduce the average volume per piece and raise the per-ton cost of logging (fig. 4) but create special handling problems throughout the logging, loading, and processing operations. Many processing machines, such as ring barkers, are not suited to handling lengths less than 12 feet. It is important, therefore, to avoid breakage in falling as much as possible. Thus, Burwell's (1972) method of line falling may have merit for older timber stands on steep slopes where the higher proportion of defect and greater weight of the trees contribute to extensive breakage losses.

Where possible, bucking in the woods should be minimized to reduce the number of pieces to be yarded and loaded. This has a beneficial effect on per-ton logging cost

and provides additional opportunity to scan the log before determining the proper log lengths for optimum value. Shattered ends should be bucked only enough to square one end of the log. In this way, chippable material available in the break can be recovered along with the merchantable part of the log. Granted, this complicates scaling and grading practice, but the benefits and costs of doing this should be considered carefully. The log bucking instructions issued by one company to insure close timber utilization follow.

> Bucking breaks and ends: (1) Clean square break--either buck through center of the break to separate the logs, or buck to give sufficient surface for adequate marking if the other end of either log is not suitable; (2) diagonal break or shattered break--buck only to provide an area for marking and to minimize further breakage in yarding; (3) broken chunk ends--buck only one end to provide an area for adequate marking.

> Bucking tops: Consider shortening the saw-log portion to upgrade the first or second log and to increase the length of the top pulp log (for better handling). Buck top to 6-inch minimum unless already broken at smaller diameter.

DEVELOPMENT OF LOG SORTING CENTERS

General.--Most simple log sorting facilities now in operation segregate saw logs from pulp logs with little or no processing equipment. However, the yard may combine log storage with sorting where, for example, pulp logs can be held in inventory while saw logs are sold as they accumulate (fig. 6).

Sorting at these log yards is generally done with log stackers that unload incoming trucks and lay the logs out on skids for scaling, if not previously scaled. The same

Figure 6.--Merchantable and substandard logs at a log sorting yard in western Washington.

machines then pile the marked logs for storage or set them aside for shipment. Utility grade logs (pulp logs) may be rebucked to yield short, higher value segments for sawing or peeling.

The second class of log yard combines sorting and some processing. These yards vary widely in complexity from a yard which merely adds a barking and chipping facility to its sorting capacity to a so-called merchandising center that diverts sorted logs to adjacent centers of use, including facilities for the production of lumber, plywood, building board, pulp, or fuel.

In the sorting yards, woods-run logs can be upgraded, particularly if these are brought to the yard in maximum length (fig. 7). This permits using the most experienced judgment in bucking for grade and value. However, this discussion is directed primarily to the handling of utility logs or other residue that may include portions suitable for lumber or veneer.

Figure 7.--Logs up to 66 feet long can be rebucked and sorted into 10 classes with this drop sorter.

Surfacing log yards.--Sorting yards must have a heavy rock base to withstand the movement of loaded 30- or 60-ton log stackers in wet weather. Even so, considerable mud and rock accumulate and mix with bark, wood, and other debris. This mixture cannot be burned readily because the rock will damage furnace grates. The cost of hauling the debris to a landfill site is substantial, and the loss of rock may be even more serious. Operators of log yards favor blacktopping as much of the log yard as possible, even though this adds to the initial investment.

Provision for log scaling.--To permit wood delivery from several sources (and thereby attain outputs that will justify the necessary log yard investment), it is important to provide a means of scaling log loads not previously scaled. This may be done by laying the load on skids for scaling by Bureau scalers. Additionally, there may be need for weighing each truckload and applying a factor or value developed through random sample scaling of many loads.

Log yard functions and equipment needs.--In addition to log sorting and bucking equipment, designers of log segregation yards may consider such equipment as: (1) barkers, (2) chippers, (3) screens, (4) hogs, (5) storage and loading bins for chips or hogged fuel, (6) splitters to size large logs for the chipper, (7) saws to break down oversize logs and recover lumber or cants where possible, (8) chipping headrigs to increase returns from small-diameter logs, (9) auxiliary equipment to handle sawdust, shavings, bark mulch, and hogged fuel separately, and (10) a drum barker to bark short or broken ends, slabs, split logs, etc., prior to chipping. The drum barker displays remarkable ability to keep the log yard free of debris and recover salable chips from much of this (fig. 8).

Figure 8.--Broken ends, swelled butts, etc., can be split and barked in a drum barker.

The more complete the yard, the higher the potential return but the higher the investment and operating cost. It is anticipated, therefore, that generally only those yards that are adjacent to a manufacturing center and which handle the equivalent of 100 million or more board feet of logs per year can justify a complete installation. On the other hand, few yards should be limited to barking and chipping equipment alone.

Currently operated log yards vary from those intended for sorting only to those that do a complete merchandising job. Some examples of each are described below.

(1) Sorting only

In its simplest form, sorting may be combined with scaling on skids. Logs are marked for segregation as they are scaled, and the log stacker makes the correct distribution when scaling is completed. Scott Paper Co. operates yards of this type at Hamilton and Lester, Washington, with pulp logs being shipped on to its more complete Riverside sorting-chipping facility in Everett.

For logs that are weight-scaled or scaled on the truck at some point, sorting may

be facilitated by use of a drop sorter providing for several sorts on each side along its length. This type of sorter can be conveniently combined with a cutoff saw and the rebucking operation performed with the sorting. A limitation is that the sorter operator does not have a good opportunity to see both ends of the log before deciding where to buck it. MacMillan Bloedel uses a drop sorter to sort saw logs and pulp logs into 10 classes at Northwest Bay on Vancouver Island (fig. 9).

Figure 9.--Handling pulpwood sorts behind a drop sorter on Vancouver Island.

A sorting table composed of live transfer chains is slower but allows more adequate time to scan a log before marking it for final use or for rebucking. Logs are carried to and from the sorting table by log stacker or front-end loader. The transfer table does not provide for convenient rebucking with the sorting, but does a good job otherwise for Scott Paper Co. at its Riverside log yard.

Mayr Brothers Logging Co. diversified its large log sorting yard on the Washington coast about 1965 by installing a splitter, drum barker, and chipper to utilize chippable logging residue. In 1973, this same yard was diversified further by opening a new band sawmill to increase return from unmerchantable and merchantable logs. The operator's experience may well provide guidelines for others in the industry as logging residue assumes increased importance.

(2) Chipping centers

Those log yards designed to facilitate chip production may provide little in the way of sorting. Thus, logs delivered to such a yard are practically committed to pulp production. However, the operators of these yards are aware of opportunities to increase timber value by segregation. Scott Paper Co., which operates two chip producing centers in Idaho, has space at one location for log sorting and storage. The firm may incorporate some sorting provision at this yard.

The chipping plant established by the Burlington Northern Railroad at Cle Elum, Washington, has been handicapped by a limited log supply and by a lack of alternate processing equipment. As prices at the pulpmill for utility logs rose in comparison with the price of chips, the operation of a remote chipping plant at Cle Elum lost meaning. The plant was maintained on a standby basis until rising chip prices in early 1974 prompted a resumption of operation.

Diamond International Corporation established a log chipping facility adjacent to its sawmill operation in Albeni Falls, Idaho. Initially the chipping plant and sawmill were operated as almost separate enterprises. This limited opportunity to divert logs or log segments from one to the other, but integration of the units is planned.

Mountain Fir Lumber Company which has built a new chipping facility on the Columbia River will transport logs or log segments suitable for sawing to its existing sawmill several miles away. The firm expects that its new venture into chip production will attract a substantial volume of additional sawable material. Furthermore, the firm regards the chipping plant as a first step in a more diversified timber utilization program.

The most elaborate log sorting-chipping center observed was the Riverside log yard of Scott Paper Co. in Everett, Washington (Davis 1971). This yard, which is designed to handle some 150 million board feet of logs per year has a log sorting table, two ring barkers (fig. 10), and a drum barker, plus chippers but no sawing equipment. Instead, saw logs segregated from logs brought to the yard were sold for export or to an adjacent sawmill. Recently, Scott Paper Co. has purchased this sawmill and may develop a new, more integrated system of selecting logs for lumber production to maximize return.

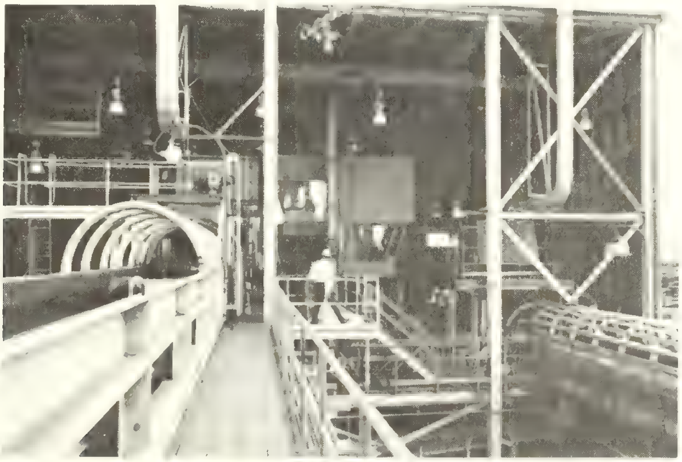

Figure 10.--Two ring barkers operated at a log sorting yard.

(3) Sorting-sawing-chipping systems

Many sawmills have experience in sawing low-grade logs and in producing chips for the pulp industry. Only a few mills that have specialized in sawing utility logs will be mentioned here to illustrate another approach to log sorting and processing facilities.

Several sawmills in Oregon, notably the Bauman Lumber Co. in Lebanon, are particularly experienced in sawing utility logs and in marketing the lumber, chips, shavings, sawdust, and hogged fuel produced. Bauman Lumber Co., in particular, is also experienced in maintaining accountability of logs from several sources. This firm's annual 60-million-board-foot operation might well be expanded into a major log segregation center with the additional barking and chipping facilities and equipment for sawing small logs.

At the West Coast Cellufibre plant in New Westminster, British Columbia, all logs pass through a hydraulic barker. Logs then go directly to a 150-inch whole log chipper or to the band headsaw for lumber production or a breakdown of the log into pieces small enough to fit the chipper. The mill provides easy access from any point to a large central residue conveyor. That conveyor takes all solid wood scrap directly to the chipper. Sawdust is stored separately for sale to pulp companies, while bark is hogged for sale as fuel. Chips are screened and loaded directly on barges or stored in one of four open piles (depending on species) for later shipment.

The benefits of combining sawing and chipping of southern pine pulp logs have been analyzed by Kaiser and Anderson (1972). Their production simulation model added a chipping headrig, trimmer, lumber sorter, and associated equipment to a typical pulpwood chipping yard supplied by logs 6 to 14 inches in diameter and 16 feet long. The added investment would amount to about $500,000. Revenue over straight chip production could be increased by $250-$700 per hour with no increase in log supply or by $500 to more than $900 per hour, if log supply were increased by 40 percent to take advantage of the increased capacity. Estimated hourly cost for the added equipment and labor was $85. The above example represents a much simpler situation than that of processing utility logs with a wide range in size and type of defect. Nevertheless, the analysis illustrates the potential gain in revenue by diversification and lists some constraints which can limit the actual gain.

(4) Complete log merchandising center

The Weyerhaeuser Company continues to build on its experience by installing improved log sorting systems that will help obtain the maximum return from each log. Since few have the raw material, the capital, and the manufacturing facilities to realize the maximum return on investment in a log segregation center, there appears need for simpler versions of log merchandising yards. The potential for simpler log merchandising centers may exist at some strategically located mills, particularly those that have experience in sawing utility logs. Mills sawing utility logs generally exist because of a need to make more complete use of an area's timber resource. It is logical, therefore, to think of these operations as a possible base for an expanded utilization center.

Research and Development Toward Further Residue Use

PRODUCT TECHNOLOGY

New pulping technology.--A major development affecting forest residue use for pulp is the growing acceptance of chips from unbarked wood. Historically, the groundwood and sulfite processes required strict limitations on bark, but the kraft and neutral sulfite semichemical processes are quite tolerant of bark (Seaton et al. 1973, Appendix K).

Horn and Auchter (1972) report the technical feasibility of producing acceptable bleached and unbleached pulp from unbarked chips of 12 western softwoods. Their work confirmed previous studies on southern pine, oak, and Douglas-fir that indicated pulp of satisfactory strength could be produced from unbarked chips. Although digester capacity is somewhat reduced in pulping unbarked chips (the fiber yield from bark is about 20 percent, compared with about 46 percent from wood), the pulping of unbarked wood offers several advantages, including:

(1) Fiber yield is increased by perhaps 10 percent. Roughly half of the increase is the fiber yield from the bark fraction and the balance is the saving of wood that is normally lost in barking.

(2) Wood that is difficult to bark because of shape is no longer a problem and now becomes available for fiber.

(3) Chipping may be done in the woods or at a remote chipping plant where bark disposal would have been a problem.

(4) Bark use as fiber and as fuel in the recovery boiler may be preferable to disposal in a landfill or to burning in a power boiler. About 75 percent of the bark is dissolved in cooking and becomes available as a source of energy. This conversion may or may not be preferred to 100-percent bark use as fuel in the power boiler, but the operator now has an added option.

The foregoing advantages are obtainable without loss in pulp strength or brightness.

The growing acceptance of unbarked chips in the pulp industry is typified by a reported experience of several firms.[9] Portable chippers can be moved to the woods on the level ground typical of the South, Lake States, and many parts of the West. In this way, entire hardwood trees can be fed to the chipper, and hardwood chip yields are double what they are in conventional harvesting. Unfortunately, this particular approach of woods chipping has more limited application to the softwood stands growing on the rugged terrain of western California, Oregon, and Washington where logging residues are most heavily concentrated.

Structural products.--New technology that permits making structural products from wood residues will extend the forest resource and help solve disposal problems. Production of structural building materials such as particleboard sheathing from logging residue or tubular framing from recycled paper add to the value and versatility of the forest resource.

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[9] American Pulpwood Association. Lake States full tree harvesting. Tech. Release 71-R-63, Dec. 1971.

The potential conversion of logging residue to particleboard for structural use is one of the more promising ways of increasing residue's utility and will be used to illustrate the importance of new technology. It has been demonstrated that particle geometry and particle alinement strongly influence the strength characteristics of the consolidated product. Research indicates that a preferred particle (flake) size (2 inches by 0.02 inch and of varying width) can be produced from logging residue, although the design of a preferred "flaking" machine has not been determined.

Strength properties and dimensional stability of the particleboard are responsive to changes in particle alinement and provide a way of achieving desired properties in a reconstituted panel by the method of forming.

The advantages gained through preferred particle geometry and alinement place the resulting product in a "structural" category, as compared with a less demanding and consequently less valuable classification. Thus, residue which is suitable for structural particleboard, as well as pulp, has an added opportunity to pay its way and escape the "disposal" category.

Other product technology.--New technology that permits increased product recovery by more accurate sawing, peeling, trimming, etc., will reduce the quantity of residue developed from processed logs. Users of chips from slabs, edgings, or trim, or users of sawdust, shavings, or sanderdust, may require additional sources of raw material. This, in turn, should encourage the recovery of more material from the woods to augment the supply of material for pulp and board production.

WOOD COMBUSTION TECHNOLOGY[10/]

Increasing shortages and rising costs of gas and oil, together with stricter limitations on residue disposal, focus attention on the energy available from wood residue. Two areas of new technology are of interest:

(1) The technology of converting wood residue (unsuited for other use) to process steam and electricity by direct combustion at large wood utilization centers without violating air quality standards.

(2) The technology of burning wood residue in a fluidized bed or in a highly turbulent furnace is being developed by several organizations. A major advantage is the potential ability to meet clean air standards without expensive emission controls. A disadvantage to date is the limited size or capacity of available units.

Potential applications of a turbulent wood-fired furnace (Energex) to veneer dryers, rotary dryers, and direct-fired kilns have been described recently by Vranizan.[11/] A prototype wood-fired, fluidized-bed furnace has operated at Coeur d' Alene, Idaho, and is now obtainable in capacities of 3 to 40 million Btu's per hour.

10/ The author is grateful to the fuels and combustion section, Construction Engineering Department of Weyerhaeuser Co., for much of the information contained here.

11/ John M. Vranizan. Utilization of wood waste to offset energy demands in the plywood mill. Presented at the "Plywood Clinic," Portland, Oreg., Feb. 1974.

Burning in a fluidized bed or in a turbulent airstream is of interest to individual forest industry plants having moderate energy requirements for lumber or veneer drying or to plants with high energy demands that seek an alternate means of controlling particulate emissions.

Fuel preparation.--Clean, dry, uniformly sized hogged fuel offers several advantages over conventional hogged fuel, including:

Improved combustion control and boiler response to load variation

Improved emission control by more complete combustion in the furnace

Increased furnace heat capacity and reduced size and cost of the installation

Increased options in fuel firing with suspension systems, stokers, traveling grates, etc

(1) Sizing--To obtain satisfactory control of combustion and particulate emission, it is advisable to size fuel to a maximum particle size of 3/8-inch (like coarse sawdust from a circular headsaw). Some tangentially fired furnaces require a smaller particle size (e.g., 1/8-inch maximum).

A combination sizing-drying method, known as a "hot" hog, is available. A unit sized for a production of 15 tons of wet fuel per hour might use a 100-hp motor on the hog and a 200-hp fan to move hot gases through the hog. Thus, the energy required for hogging would be about 14 hph per bone-dry ton. By comparison, about 8 hph per ton are required to produce softwood pulp chips.

(2) Drying--Predrying can be accomplished more efficiently in a dryer than in a boiler furnace because the exit temperature from the dryer may be as much as 150°-400° F lower than stack gas temperature. Fines and dirt can be removed after predrying and before burning, thus aiding control of combustion for higher efficiency and better air quality control.

There are a variety of drying systems available for predrying wood or bark fuel, including presses, rotary dryers, flash dryers, hot hogs, and heated conveyors.

Rotary dryers, such as those used for drying wood particles for board production, foodstuffs, lime, etc., are among the most efficient. The Heil dryer is well known in the particleboard industry, and the Stearns-Rogers dryer is widely used in the food industry. The latter has the advantage of being available in larger capacities capable of drying 200,000 to 300,000 pounds of material per hour. The latter dryer also operates at a lower overall temperature which favors more uniform drying.

An auxiliary furnace is recommended to provide the hot gas for the dryer. Fines from a cyclone separator on the dried-fuel output line will provide the auxiliary furnace fuel. Although this may require 10-15 percent of the hogged fuel input, there may be an overall saving of 5 percent in fuel because of improved efficiency. Also, two-thirds of the gas, dust, and fumes from the cyclone may be recycled to the auxiliary furnace. Flue gas from the boilerhouse stack is not always suited or available for fuel drying. It is desirable to hold stack gas temperatures between 400° and 450° F, and this is too low for good controlled drying. Flue gas does have the advantages of being free and

noncombustible. Unfortunately, it may be uneconomical to bring the gas from the stack to the point where the fuel is to be dried, or the total heat available in the stack gas may not be sufficient to do the required drying.

The rotary dryer is well suited to predrying coarse fuel, as the fuel has a residence time of 10-20 minutes.

The hot hog, a form of flash dryer, is well suited for a fine fuel output and may encourage development of lower cost furnaces that fire fuel in suspension. Its operation is similar to that of the pulverizers that have been used to grind and dry coal for many years. The hog can react quickly to fluctuations in fuel requirements. Fines from a cyclone on the dry fuel line are returned to the air heater as fuel. Gas goes from the air heater to the hog at 700°-1,000° F. Outlet temperature of gas from the hog is about 200° F.

Hot conveyors may be used to remove surface moisture and dust from hogged fuel. Wet wood is conveyed on a vibrating, moving screen over a pressurized plenum. The plenum is heated with boiler stack gas at 400°-600° F or with gas from a dust-fired, air heater at 600° F. Dust and fines pulled off through a stack in the conveyor hood may fuel the air heater. Fuel may be dried from 50- to 70-percent moisture to the moisture level desired for the firing equipment available.

Furnaces for direct combustion.--Wood-burning furnaces which have been described by Corder (1973) may be of several types, including:

(1) Deep bed, pile burners, such as the Dutch oven;

(2) Thin bed burners with stationary pinhole grates, inclined grates, dump grates, step grates, or traveling grates;

(3) Suspension burners such as those used for pulverized coal, the register type, or the newer "cyclone" types, including the Combustion Equipment Associates (CEA double vortex furnace) and the Energex furnace.

A wood-fired furnace and boiler may cost \$10-\$20 per pound of steam per hour capacity but will vary with the size of the installation. For example, an installation producing 125,000 pounds of steam per hour may cost \$18 per pound of steam (vs. about \$4 per pound for a gas- or oil-fired packaged boiler) or \$13 per pound of steam for a 250,000-pound boiler (vs. about \$3 per pound for gas-fired).

The added cost of the wood-fired boiler results from such things as:

(1) The need for grates and other ash handling equipment,

(2) Higher fuel storage and handling cost,

(3) Increased surface for heat transfer due to lower furnace temperatures resulting from high water content of the fuel,

(4) Particulate control equipment which adds increasingly to the total installation cost. Roberson (see footnote 7) estimates that air emission controls have added 13-15 percent to the energy requirements of a kraft pulpmill and will have added about 25 percent when SO_2 and NO_x flue gas removal systems are installed.

(5) The need to field-erect the wood-fired furnace and boiler (vs. assembly of packaged boilers or modules). Capacity of packaged boilers for wood is limited to 10,000 to 100,000 pounds per hour. Modular types for wood are available in 50,000 to 350,000 pounds per hour, although one major manufacturer has produced shop parts for a boiler with a capacity of 800,000 pounds per hour.

(6) Hot gases must travel at lower velocity because of entrained ash that can erode tubes or other boiler surfaces.

Particulate emission control.--Control of particulate emissions to meet air quality standards may be achieved by optimizing combustion, by cleaning the stack gases, and by avoiding reinjection of fly ash into the furnace.

(1) Combustion is optimized by proper design, operation, and maintenance of the unit. Proper operation includes sizing, cleaning, and drying the fuel. Additionally, the vertical furnace velocities may be lowered--to reduce carryout of particles--by predrying the fuel to decrease the volume of flue gas or by installing a larger furnace.

(2) Stack gases may be cleaned to comply with air quality standards by installing such equipment as: multiclone (cyclone) collectors; wet scrubbers (which are not fully developed for wood); bag houses (which are widely used in metallurgical industries for fine dust, but which only recently have been applied to a bark-fired furnace); or electrostatic precipitators.

When used to clean stack gases from a recovery boiler at an 800-ton-per-day pulpmill, a bag house would cost about the same as electrostatic precipitators. Fiberglass bags are good for temperatures to 500° F and should last 6 to 24 months. Adams[12/] favors a bag house wherever an efficiency of greater than 99 percent is required.

Electrostatic precipitators are used in combination with multiclones, but even then they may not achieve the planned efficiency, if over 99 percent is required. Experience with precipitators on wood-fired furnaces is very limited, and there is some concern about an explosion hazard with finely divided carbon where arcing is possible. Collection efficiency is assumed to be lower than on recovery boilers where salt cake is present.

New collection methods, which are being studied, may provide a better means of cleaning stack gases than systems currently available.

(3) Avoid reinjection of fly ash into the main furnace by burning it in a small fluidized bed or suspension burner.

Electric power generation.-- A pulp-and-paper mill will require from 15,000 to 20,000 pounds of steam per ton of product and from 700 to 1,400 kWh of electric power per ton. Thus, much of electrical needs can be produced by byproduct power generation (see footnote 7).

12/ A. B. Adams. Energy for mill operations--chemical recovery, recausticizing and lime burning. Talk at University of Wisconsin Extension Division short course, "Energy and the Pulp and Paper Industry," Milwaukee, Wis., Oct. 1973.

Assuming average boiler efficiency, plant heat rates are 10,000 Btu per kWh for an oil- or coal-firing utility and 12,000 Btu per kWh when firing wood. Comparable heat rates at a pulpmill are 4,500 Btu per kWh firing oil and 6,000 Btu per kWh firing wood or spent cooking liquor (see footnote 7).

Also, capital costs may be much less for power generation at a forest industry plant (e.g., $150/kW of rated capacity vs. $300/kW for a utility).

Systems for generating power from wood residue.--Some possible combinations of fuel preparation-combustion systems and of combustion-power generation systems have been described by Johnson (see footnote 10). Some such systems are illustrated in the appendix. Johanson and Sarkanen,[13/] after reviewing many gasification systems, recommended a system that is illustrated in the appendix.

The technology of gasification systems, including the fluidized bed, is not fully developed. However, Combustion Power Company has a pilot unit that is close to commercial production. This pilot program, designed for solid waste disposal, has been supported by funds from the Department of Health, Education, and Welfare but appears adaptable to moderate-sized, wood-fired units where it could help improve the technology of fluidized bed combustion. More recently, a prototype fluidized-bed furnace burning wood residue at Coeur d' Alene, Idaho, has provided a basis for commercial production.

Application of new combustion technology in forest industry plants.--It seems increasingly evident that the bulk of the forest residue consigned to energy production will be burned at forest industry plants rather than outside the industry (Grantham et al. 1974). This is because of the industry's stronger competitive position as compared with electric utility companies or plants converting wood to energy by way of methanol, methane, oil, etc.

In short, a forest industry plant already established to manufacture wood-based products does not require a long-term commitment of residue to insure amortization of a multimillion-dollar plant investment. Although the investment in a residue-fired furnace, boiler, and auxiliary equipment is substantial, this will enable a forest industry plant to divert bark and low quality wood to fuel. This provides annual savings in fuel cost; but more important, it reduces reliance on gas and oil and avoids the possible loss of revenue through a forced shutdown.

ADMINISTRATIVE CHANGES FOR FULLER TIMBER UTILIZATION

In 1972, the Close Timber Utilization Committee of the Forest Service provided a series of recommendations designed to make forest land management responsive to current and foreseeable needs. These include five recommendations for change in contract specifications (or standards) and procedures.[14/]

[13/] L. N. Johanson and K. V. Sarkanen. Means of converting wood residues to energy other than through combustion. Contract report to Pacific Northwest Forest and Range Experiment Station, Dec. 1972.

[14/] Report of Close Timber Utilization Committee, USDA Forest Service, Washington, D.C., Apr. 1972.

To meet the changing situation, the Forest Service has experimented with various means of obtaining more complete timber utilization. One means has been to make only a nominal per-acre charge, or no charge, for removal of timber smaller or more defective than the minimum contract requirements; another has required yarding of unmerchantable material to reduce the fire hazard of scattered heavy residue and to improve land management generally. Per-acre costs of yarding unutilized material (YUM) have been high and have reduced stumpage return substantially. Dowdle (1973) has questioned the basis on which a decision is made to yard unutilized material on a particular timber sale.

The Bureau of Land Management uses lump sum timber selling on its lands in western Oregon as a means of achieving closer timber utilization. It was reasoned that timber purchasers would have greater incentive to remove everything that would pay its way out of the woods and that they would have greater flexibility in falling and bucking practices since no log scaling was required. The advantages and disadvantages of lump sum selling have been debated extensively, but to date other major public timberland managers have made only limited use of the system.

The close utilization policy adopted by the British Columbia Forest Service in 1966 was designed to improve utilization by lowering the minimum stump diameter (tree size) from 14 to 10 inches and the stump height from 18 to 12 inches. The minimum top diameter was decreased from 8 to 6 inches.

The policy was adopted primarily for the interior forests of the Province, where the timber is smaller and the ground flatter than on the coast. To encourage adoption of the new policy, the B. C. Forest Service provided two incentives. First, the operator or licensee was permitted to increase his annual allowable log harvest by the indicated difference in cruised timber volume--using the old and new utilization standards. Second, this additional cruised volume was charged at a nominal stumpage of $0. 55 per cunit and prorated with normal appraised stumpage to give an adjusted stumpage rate. This adjusted rate applied to all logs harvested.

Since the large timber on the steep terrain west of the Coast Mountains presented more difficulty in logging, a 5-year moratorium, and later, a 1-year extension, was granted on adoption of close utilization standards. Only recently has the B. C. Forest Service begun to enforce an accounting of every piece with minimum dimensions of 6 inches in diameter and 8 feet in length, providing the piece contains 50 percent or more of firmwood (chippable wood). Companies are still experimenting with modifications in their forestry and logging practices to determine the best means of meeting the new standards.

Attempts to improve timber utilization on public lands west of the Cascade Mountains in the United States or west of the Coast Mountains in British Columbia have met with limited success. Thus, there is a seeming need to better inform the public, the industry, and key public officials about forest land management goals. Frear (1973) has described the importance of agency communication vs. confrontation in gaining public support of land management programs. There is a need for forest land managers and owners to better inform the general public, environmentalists, key public officials,

and forest industry representatives of the importance of complete timber utilization to forest land management, plus long-term gains in resource value, employment, and expansion of the tax base.

Forest Land Management or Service Contracts

There have been many proposals for changes in timber sale procedures to help achieve land management goals, but there are both economic and political obstacles to procedural changes. These obstacles slow adoption of such changes as those summarized below:

(1) Use simplified estimating procedures and negotiated lump-sum contracts for residue sales where appraised values are small. This procedure might be more useful if the authorized limit on negotiated sales were raised from $2,000 to $10,000 as has been proposed.[15]

(2) Use a service contract with free salvage rights to remove logging residue (as recommended by the Close Timber Utilization Committee, see footnote 14). The contract would specify the degree of removal required and leave the contractor free to recover such values as he can. It has been suggested that any service contract be so written that the contractor has maximum flexibility in his choice of equipment and methods to meet the contract requirements. Understandable and enforceable contract specifications are essential. It is also necessary to enforce contract compliance uniformly and consistently to emphasize a commitment to forest land management goals.

(3) Use a compound contract, which combines a logging contract with a product sale contract, as proposed by the President's Advisory Panel on Timber and the Environment (Seaton et al. 1973). The logging contract describes services to be provided by the contractor and a payment schedule for such services; the product sale contract provides for purchase of merchantable timber produced in the logging contract by the same contractor under a payment rate established by bid.

Suggested Changes in Sale Procedures

In considering changes in sale procedure, some suggestions of the industry are pertinent:

(1) Although measurement of standard (merchantable) and substandard wood should be simplified in every way possible, there is advantage in scaling both standard and substandard material to provide wood accountability for all parties, including land managers, contractors, subcontractors, loggers, truckers, and log purchasers.

(2) Sale procedures should be modified to provide for a quick response to market changes. For example, (a) respond to an increased demand for chips from substandard material by offering formerly marginal sale offerings quickly through temporary transfer of personnel and employment of outside help to be paid from receipts; (b) extend contract without penalty, if the chip market declines temporarily.

(3) One other suggested change is for required removal or early release of the residue on each cutting unit to facilitate possible salvage through a new sale.

---

[15] Comptroller General's report to U.S. Congress. More usable dead or damaged trees should be salvaged to help meet timber demand. Oct. 1973.

Current Research on Contractural Procedures

Responding to the expressed need for new contractural procedures to encourage more intensive timber utilization, the Pacific Northwest Forest and Range Experiment Station is conducting four related studies that should be useful to contract writers. The studies include:

(1) Effects of forest residue and residue treatments on the environment: a compendium of current knowledge to aid in establishing interim forest management guidelines (Cramer 1974).

(2) Guidelines for forest residue management.[16/] This study, based on the above compendium, aims at setting forest residue management guidelines that are scientifically sound and administratively achievable.

(3) Alternative sale arrangements--a cooperative study with the Bureau of Land Management to give its district managers more timber sale options to achieve land management objectives. The guidelines developed in (2) should be valuable in drafting pilot contract procedures.

(4) Shelton cooperative residue utilization study. The cooperative sustained yield unit at Shelton provides an opportunity to evaluate such measures as line tree felling or modified bucking practice and log sorting for highest value use that have been proposed to improve timber utilization. This 3-year cooperative study between Simpson Timber Co. and the Forest Service was begun in the spring of 1974.

16/ Paper being prepared by Pacific Northwest Forest and Range Experiment Station.

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APPENDIX

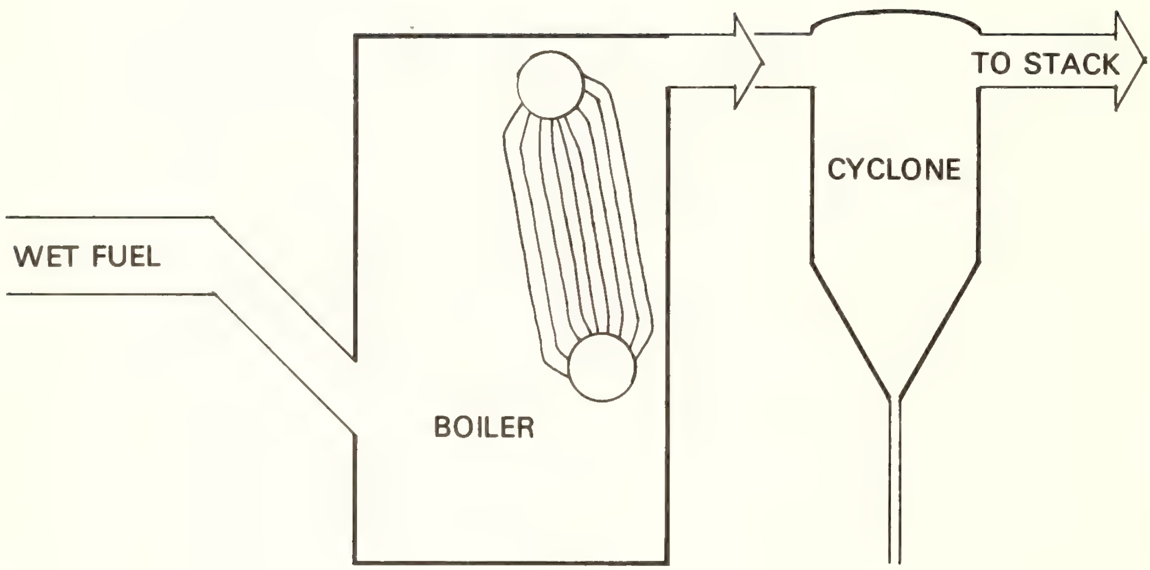

Figure 11.--Conventional wood-fired boiler.

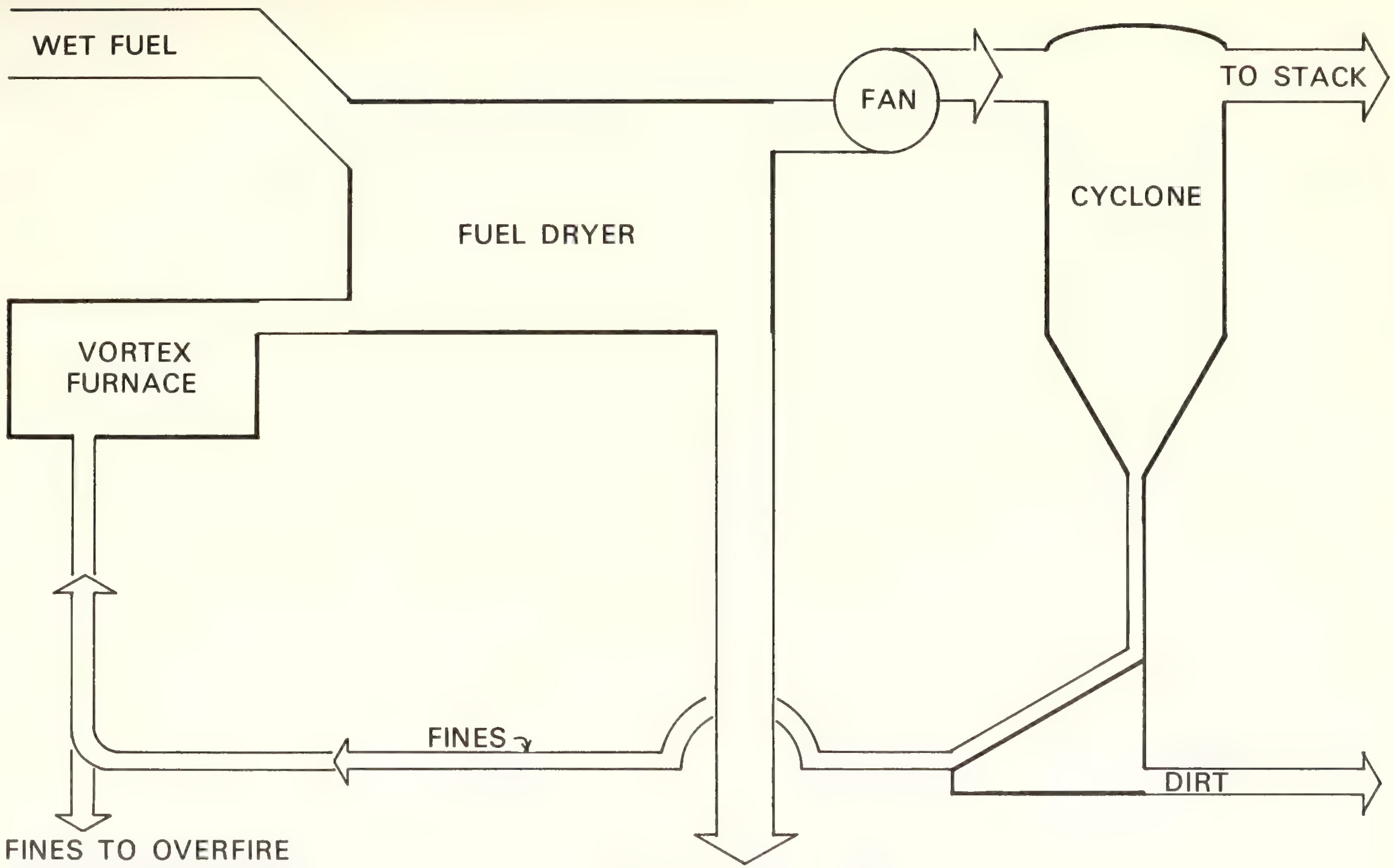

Figure 12.--Fuel drying system (to 35-percent moisture content) for use with a conventional wood-fired boiler.

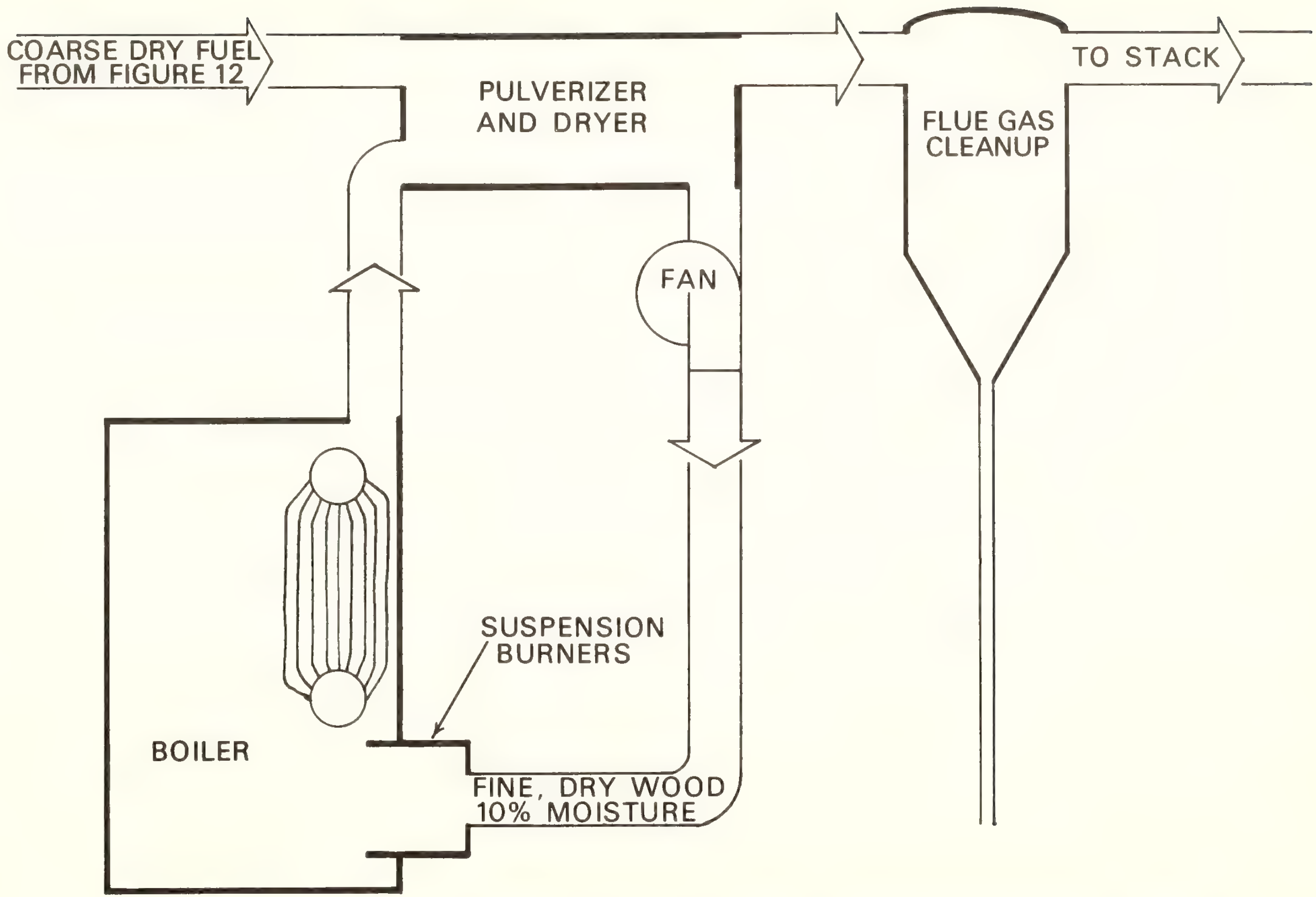

Figure 13.--Boiler with suspension firing of wood at 10-percent moisture content.

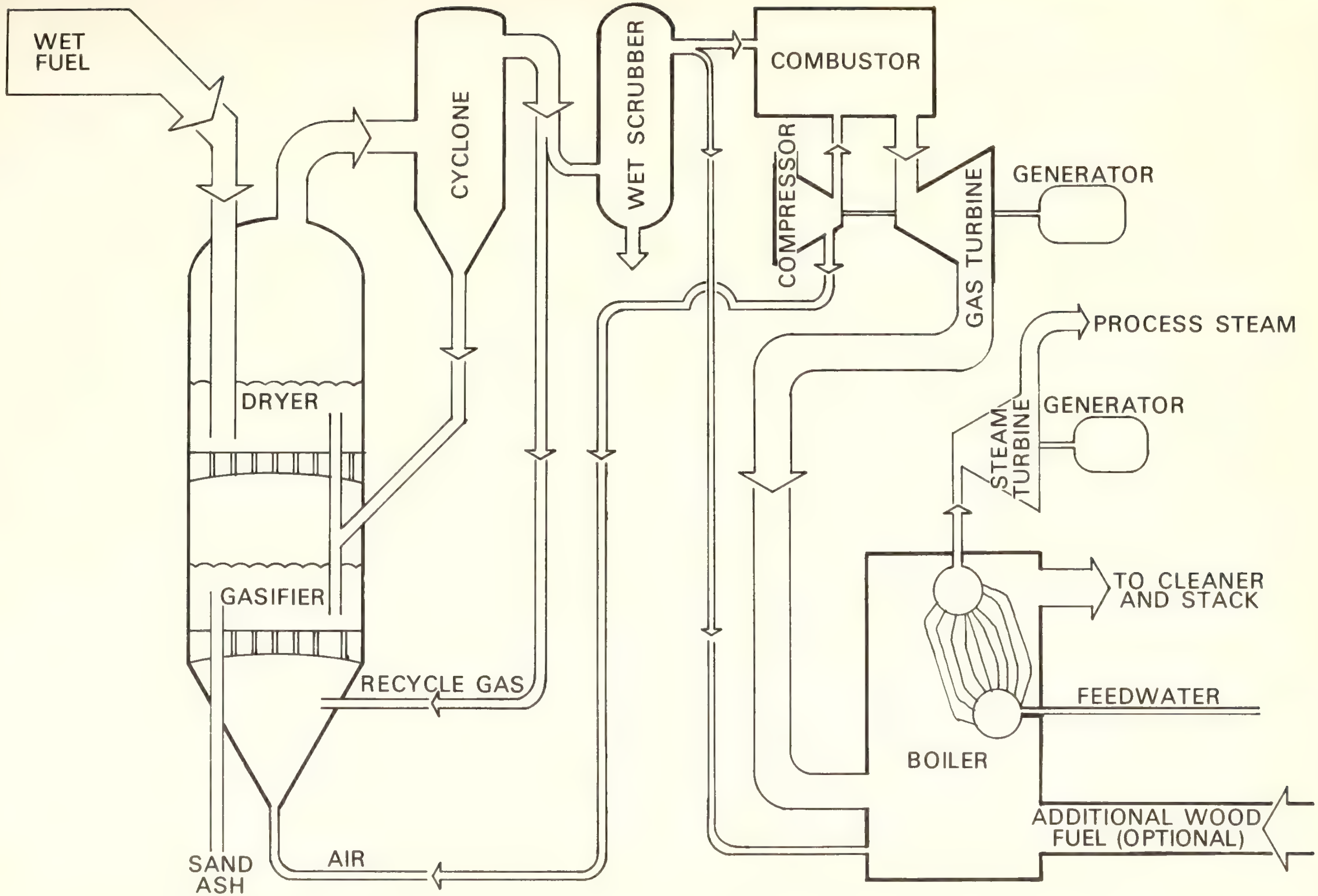

Figure 14.--Wood gasification and combined gas turbine-steam turbine electric power generation (as conceived by Johanson and Sarkanen, see footnote 13).

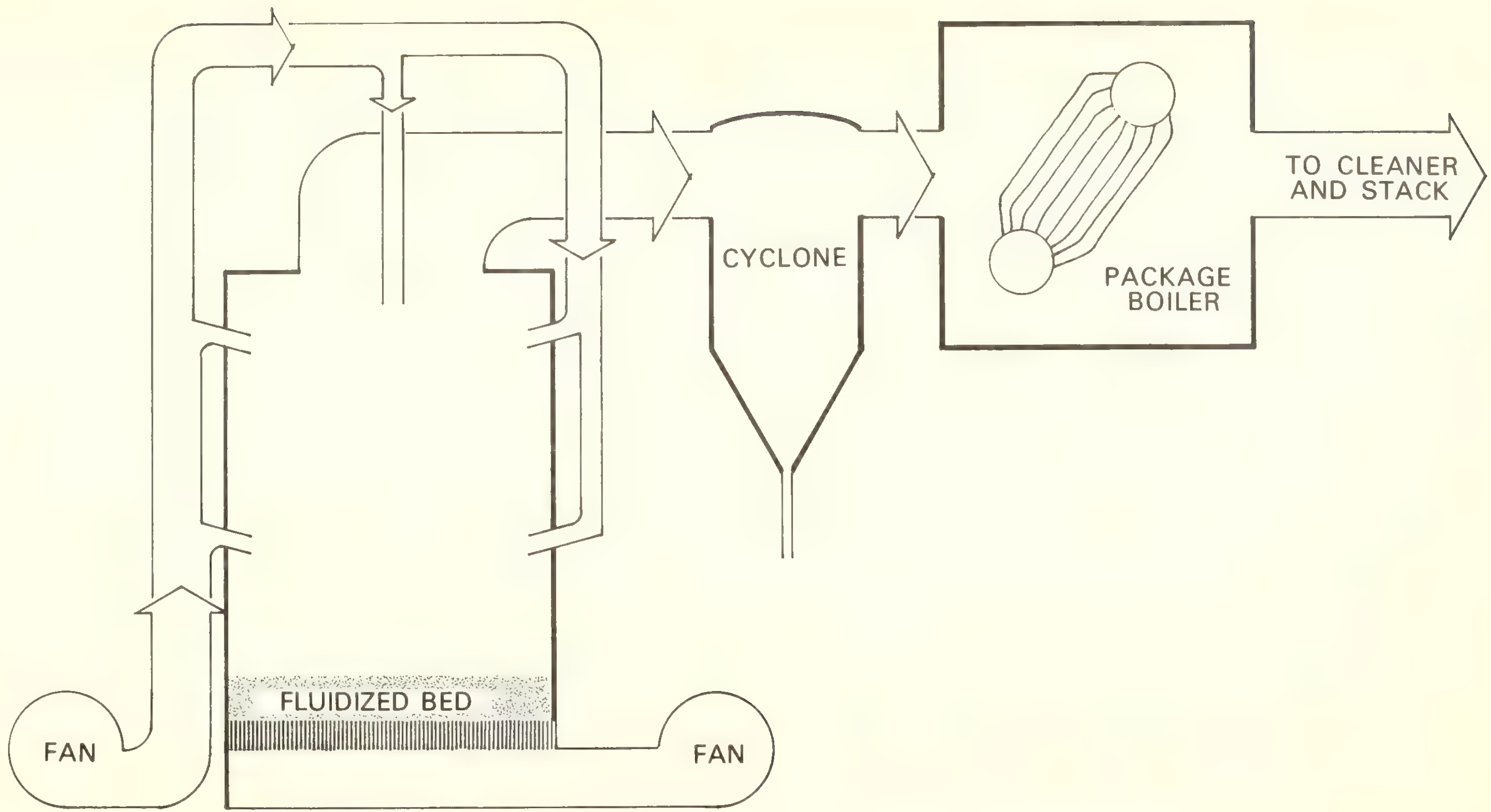

Figure 15.--Fluidized-bed furnace for hot gas or steam generation.

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ABSTRACT

Production of merchantable wood in even-aged Douglas-fir stands can be increased substantially by precommercial thinning. Guidelines for, and gains from, precommercial thinning both strongly depend on the size of trees wanted at the first commercial cut; the larger this size, (1) the fewer trees should be left after precommercial thinning, (2) the greater is the maximum age or tree size at which precommercial thinning is practical, and (3) the greater is the gain in usable yield from precommercial thinning. Also, generally, the longer the time required for a stand to reach commercial size without thinning, the greater the gains from precommercial thinning. These and other considerations are discussed, and procedures are recommended.

KEYWORDS: Douglas-fir, precommercial thinning, stand improvement, stocking control, stocking density.

CONTENTS

INTRODUCTION

Precommercial thinning is a practical means of substantially increasing the production of usable wood. The larger the trees must be to be merchantable, the greater are the gains from precommercial thinning.

This paper provides guidance on when and how to precommercially thin stands of nearly pure Douglas-fir. Relative gains from selected options are indicated; however, the complete information needed to rank management alternatives is beyond the scope of this paper. Conclusions and recommendations given are my opinions, based on observations and available data. Although I believe the recommendations are sound, I am concerned more with presenting concepts than with specific recommendations.

The first part of this paper is concerned with thinning at the "ideal" stage--the stage at which precommercial thinning will have the greatest effect on subsequent usable production. After this, some considerations regarding stands which have passed this stage are discussed.

WHEN TO THIN

Ideally, stands should be thinned when leave trees are about 10 to 15 feet (3 to 5 m) tall and 10 to 15 years old (fig. 1). Thinning should be delayed only long enough for trees to express their growth and quality characteristics and to be above such deterrents as brush competition and animal browsing. Further delay will usually result in unnecessary loss in usable production and will often result in increased thinning costs.

A 10-year period of growth is generally sufficient to show potential growth rate, stem and branching characteristics, and susceptibility to various types of damage. On the best sites, dominant trees will average about 15 feet (5 m) tall at this age, and the stands will be ready for thinning. However, on poor sites, 10-year-old trees will be quite short and susceptible to damage; therefore, thinning on the poorest sites should be delayed to about age 15 (fig. 1). Ages and heights of trees on intermediate sites will fall between these extremes.

The longer the delay of thinning after competition among trees begins, the greater will be the unrealized usable production. First, substantial growth will be added to trees which will never be used, and therefore, less growth will be added to trees which subsequently will be used. Tree growth begins to be reduced by competition well before that competition becomes readily apparent; by the time lower branches start dying, competition is already quite substantial. Second, trees in dense stands are more susceptible to storm damage than are well-spaced trees in thinned stands, once the latter have adapted to their increased growing space. The older the stand when thinned, the longer the adaptation period.

Thinning can generally be done more cheaply and efficiently when trees are small. Excess trees can then be easily felled, with few problems. Care should be taken to cut stumps below the lowest live branch, if possible. If felling of excess trees is delayed until trees become larger, it will create a larger amount of slash, which may have to be abated, and is likely to damage residual trees and to cause "shock." Killing these larger trees with chemicals, rather than felling them, will avoid the slash and shock problems but often results in incomplete kill of unwanted trees or loss of some intended leave trees, or both.

In most situations, fill-in by natural seedlings after age 10 should be

inconsequential. The trees left after thinning will be in the period of most rapid height growth and will not give new seedlings an opportunity to become competitors. Likewise, brush encroachment generally should not be a severe problem. Where severe brush problems exist prior to thinning, chemical control of the brush should be considered.

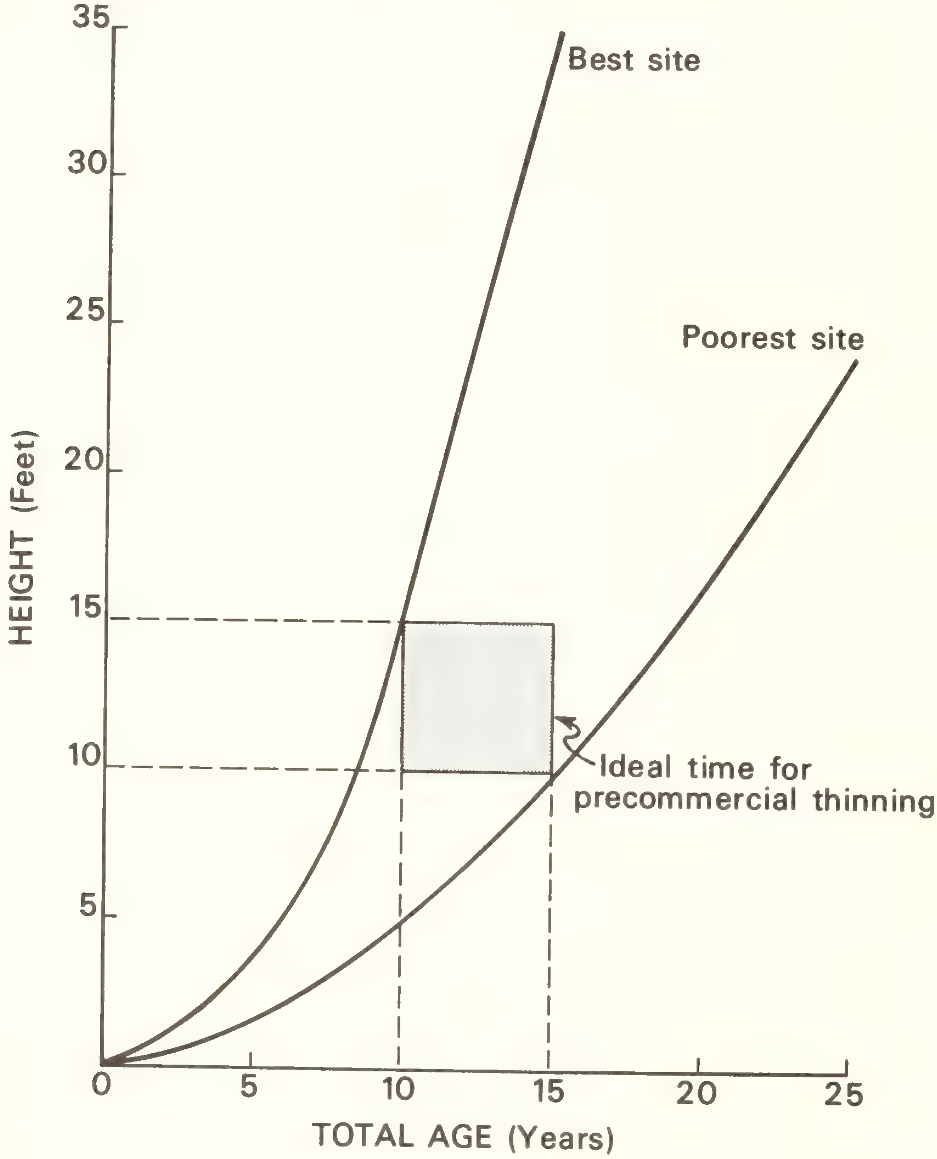

Figure 1.--*Ideal time for precommercial thinning of Douglas-fir relative to height and age of leave trees.*

SPACING OF TREES

The number of trees left after precommercial thinning should depend upon when the first *commercial* thinning will be made--in terms of tree size at that time.[1] The larger the trees must be to support a commercial thinning, the fewer the trees left after precommercial thinning.

A guide to the desired number or spacing of trees is provided in figure 2. This format shows stocking at any point in time--in terms of stand average d.b.h. (Dq),[2] number of trees, and basal area. As long as there is no mortality, the development of *a stand* with increasing age (increasing tree size) is depicted by a vertical progression upward. The "desired maximum stocking" curve shows the basal area per acre and stand average d.b.h. which stands of various densities (number and spacing of trees) can be expected to attain by the time another thinning is needed. It is applicable to all sites; only the timespan differs. The position of this curve is based on experience with experimental plots, plus a consideration of how stands develop.[3]

Precommercially thinned stands will generally attain this level with no suppression-related mortality. Thus, the point at which desired average diameter at the time of commercial thinning intersects this "maximum" curve determines the number of trees to be left after precommercial thinning. For example, if average d.b.h. of the stand must be 8 inches (20 cm) at the time of the commercial thinning, the stand should be precommercially thinned to about 400 trees per acre (1,000 per ha). If it needs to be only 6 inches (15 cm), 610 trees per acre (1,520 per ha) should be left; if it must be 10 inches (25 cm), only 290 trees per acre (720 per ha) should be left. The average spacing of these trees is closely approximated by $D+2$ feet; where D is the average d.b.h. at the time of the *next* (commercial) thinning, *not* the precommercial thinning. If no commercial thinning is deemed practical, even fewer trees should be left--perhaps 150 to 200 per acre (370 to 490 per ha).

This stocking guide is intended to be used for *spacing*, not for absolute number of trees per acre. Most stands contain openings not occupied by trees. Therefore, the average number of trees left per acre should generally be less than called for by the stocking guide. One should *not* maintain an overdense stand in one spot to offset the lack of trees in another. As a rough guide, the maximum number of extra trees left around an opening should be the number obtained by extending the desired spacing pattern one more space into the opening. The spacing between any two residual trees should be no less than one-half the desired average spacing (fig. 3). Thus, using these guides, we *might* compensate for holes with a width of up to twice the desired average spacing by leaving extra trees around the perimeter, provided trees are present in the right places. Any hole larger than this cannot be fully compensated for. Extra trees left to compensate for an opening should be left only around the immediate perimeter of that opening. They should *not* be crowded into other parts of the stand.

Elsewhere within the stand, an attempt should be made to maintain the

---

1/ If the stand will be carried to final harvest with no commercial thinning, then the reader should substitute "harvest" for "first commercial thinning" throughout the paper.

2/ As used in this paper, average d.b.h. is the quadratic mean d.b.h., or d.b.h. of a tree of mean basal area.

3/ Details and supporting evidence are on file, Forestry Sciences Laboratory, Olympia, Washington.

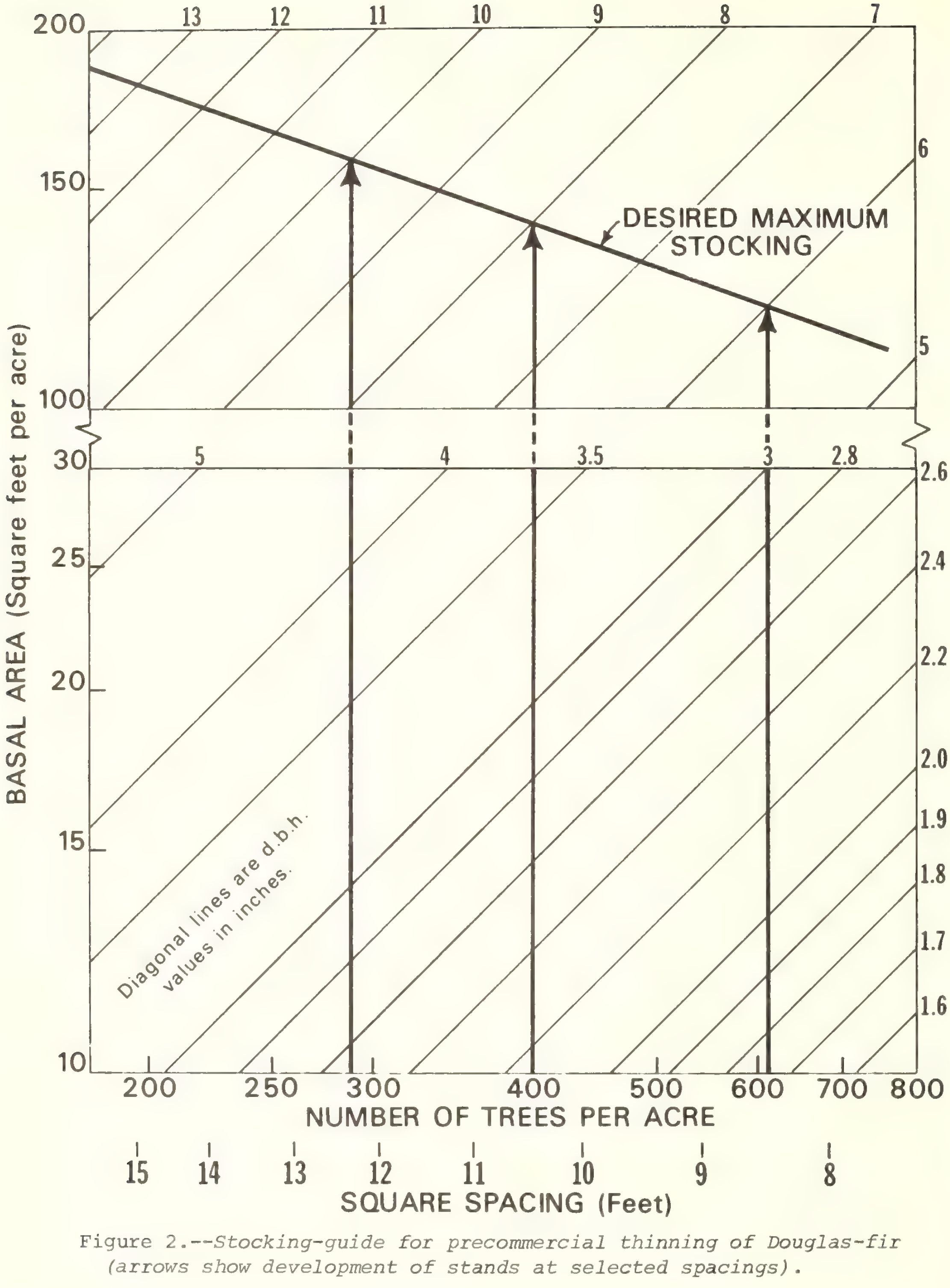

Figure 2.--*Stocking-guide for precommercial thinning of Douglas-fir (arrows show development of stands at selected spacings).*

IDEALIZED SPACING

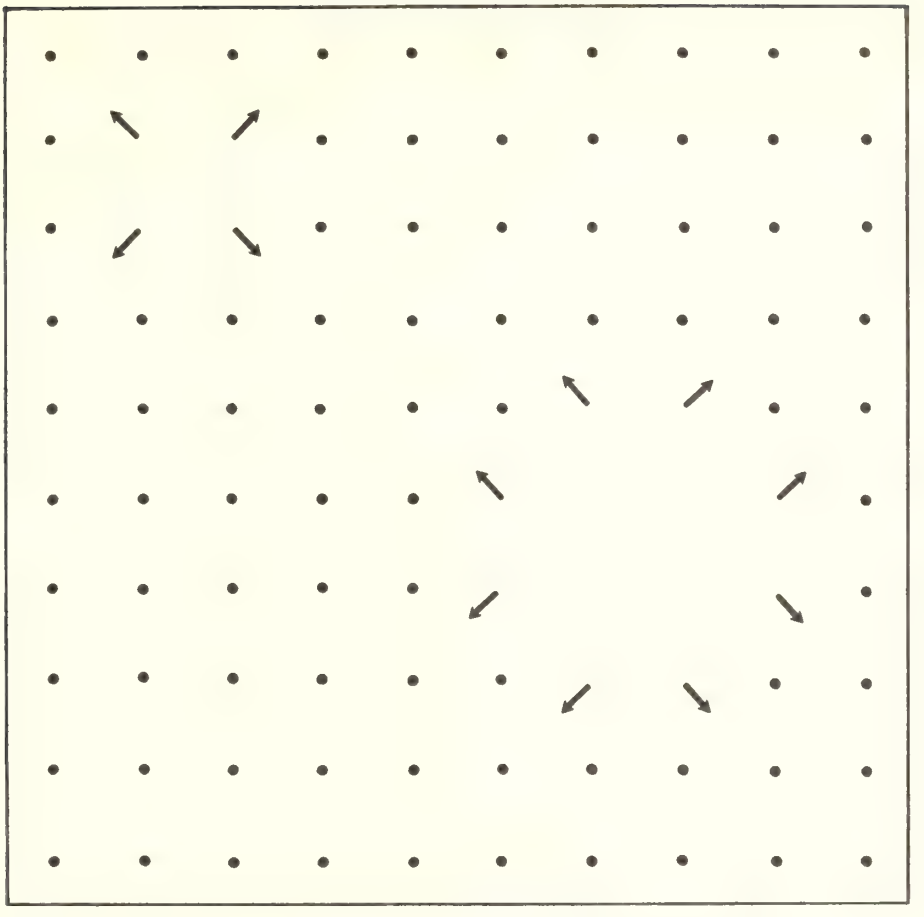

Figure 3.--*Effect of stand openings on number of leave trees per acre (arrows show where extra trees could be left on the perimeter of openings).*

desired *average* spacing around each tree, as nearly as possible. Thus, crowding on one side of a tree should be compensated for by extra space on another side. This condition can, of course, seldom be achieved exactly. However, in no case should several adjacent trees be crowded. The number of trees actually left per *stocked* acre should not be more than 10 percent greater than the number called for by the guide.

The spacing recommended in this guide is expected to allow all trees to reach merchantable size; the minimum merchantable size is assumed to be about 25 percent smaller than the specified average diameter of the stand (*Dq*). It is further expected that when the desired *Dq* is reached, most trees will still be growing well and will respond well to release. With more trees than this, growth of individual trees begins to be seriously retarded before trees become large enough to support commercial thinning, and some trees will die. The first commercial thinning will remove up to one-third of the trees, with average d.b.h. of cut trees about equal to average d.b.h. of the entire stand.

SELECTION OF LEAVE TREES

Precommercial thinning at the ideal stage should strive for uniform size of trees as well as spacing. One should attempt to leave trees having diameters within ± 25 percent of the average for all leave trees within that portion of the stand. Thus, if average d. b. h. of all leave trees is 2.0 inches (5.1 cm), the maximum range should be about 1.5 to 2.5 inches (3.8-6.4 cm). If smaller trees are left, they would generally be crowded out of the stand. On the other hand, if larger trees are left, they tend to grow at an excessive rate and adversely affect their neighbors.

There is some question regarding the need to cut very small understory trees. In some instances, they could be left and would soon be crowded out of the stand. However, if they have good root systems, they could grow quite rapidly and become competitors. As a general rule, it is best to remove all unwanted trees.

STANDS PAST THE IDEAL STAGE

Gains in usable yield from precommercial thinning are greatest if thinning is done at the ideal stage, and stands at that stage generally should not be bypassed in favor of thinning otherwise comparable stands which have passed that stage.[4/] However, there are still opportunities for substantial gains from precommercial thinning of somewhat older stands, although a marginal point is soon reached, beyond which precommercial thinning is no longer practical. This point will vary with site quality, stand structure, expected markets for small trees, management objectives, and type of ownership.

[4/] Gains in undiscounted dollars, and likely even in discounted dollars, will also be greatest with early precommercial thinning.

A primary gain from precommercial thinning is a shortening of the time a stand must be carried before it can be commercially thinned. Generally, the longer the time required for trees to reach commercial size without thinning, the greater the gain from precommercial thinning. Thus, the larger the trees must be to support a commercial thinning, the greater the gain. Likewise, up to a point, the more slowly the trees are growing, the greater is the gain.

If precommercial thinning is delayed, trees will be substantially older when they reach the desired size for commercial thinning. First, leave trees will be smaller at the time of precommercial thinning than they would be at that age if the stand had been thinned earlier. Second, they will continue to grow more slowly for the next few years than they would if the stand had been thinned earlier. I am reluctant to give specific estimates but have done so for the purpose of illustrating a *concept*. These estimates are based on the assumption that the stands, before thinning, are "normal."[5/] Obviously, the ages for both unmanaged stands and stands receiving precommercial thinning will vary somewhat with initial stand density, among other factors.

Estimated gains in time are shown for three commercial thinning options: thin when *average* d.b.h. of merchantable trees is (I) 8 inches (20.3 cm), (II) 9 inches (22.9 cm), or (III) 10 inches (25.4 cm) (table 1). If *minimum* merchantable size is 25 percent smaller than

[5/] Normal by site and age, according to Richard E. McArdle, Walter H. Meyer, and Donald Bruce, The yield of Douglas-fir in the Pacific Northwest, U.S. Department of Agriculture Technical Bulletin 201 (revised 1961), table 2. (Reprinted by Oregon State University Book Stores, Inc., Corvallis, Oregon, 1971.)

Table 1.--*Estimated gain in age of Douglas-fir at which first commercial thinning can be made, for selected conditions*

Precommercial thinning (PCT) options and treatments	Site				
	I	II	III	IV	V
	Gain in years[1/]				
Option I (400 8-inch trees):					
Ideal PCT time[2/]	4	5	6	10	16
PCT at age 20	--	--	--	6	11
PCT at 30 feet	2	3	3	5	2
Option II (335 9-inch trees):					
Ideal PCT time[2/]	6	7	9	13	21
PCT at age 20	--	--	--	9	16
PCT at 30 feet	4	5	5	8	7
Option III (290 10-inch trees):					
Ideal PCT time[2/]	7	9	11	16	26
PCT at age 20	--	--	--	11	21
PCT at 30 feet	5	6	7	11	12

1/ Age without precommercial thinning minus age with precommercial thinning.

2/ When leave trees are 10-15 feet tall and 10-15 years old.

these stand averages--i.e., 6.0, 6.75, and 7.5 inches (15.2, 17.1, and 19.0 cm), the corresponding numbers of merchantable trees for each of the three options will be about 400, 335, and 290 per acre (990, 830, and 720 per ha), respectively. For precommercially thinned stands, this is the total number of trees in the stand. For unmanaged stands, many additional trees will die without reaching merchantable size. For each option, gains with (1) precommercial thinning at the ideal time and (2) precommercial thinning when leave trees are 30 feet (9.1 m) tall are shown; for sites where trees are more than 20 years old when they reach a height of 30 feet (fig. 4), precommercial thinning at age 20 is also included. Stand ages associated with these gains are shown in table 2.

Gains from delayed precommercial thinning in stands where leave trees are up to 30 feet (9 m) tall or 20 years old, whichever comes sooner, are still substantial, although much less than gains from earlier thinning. Gains from thinning after about age 20 decline very rapidly. This is the approximate age at which current annual height growth culminates. The differences in gains for the three commercial thinning options are due to differences in merchantability standards. If smaller trees could be used, then gains from precommercial thinning would be less than in option I.

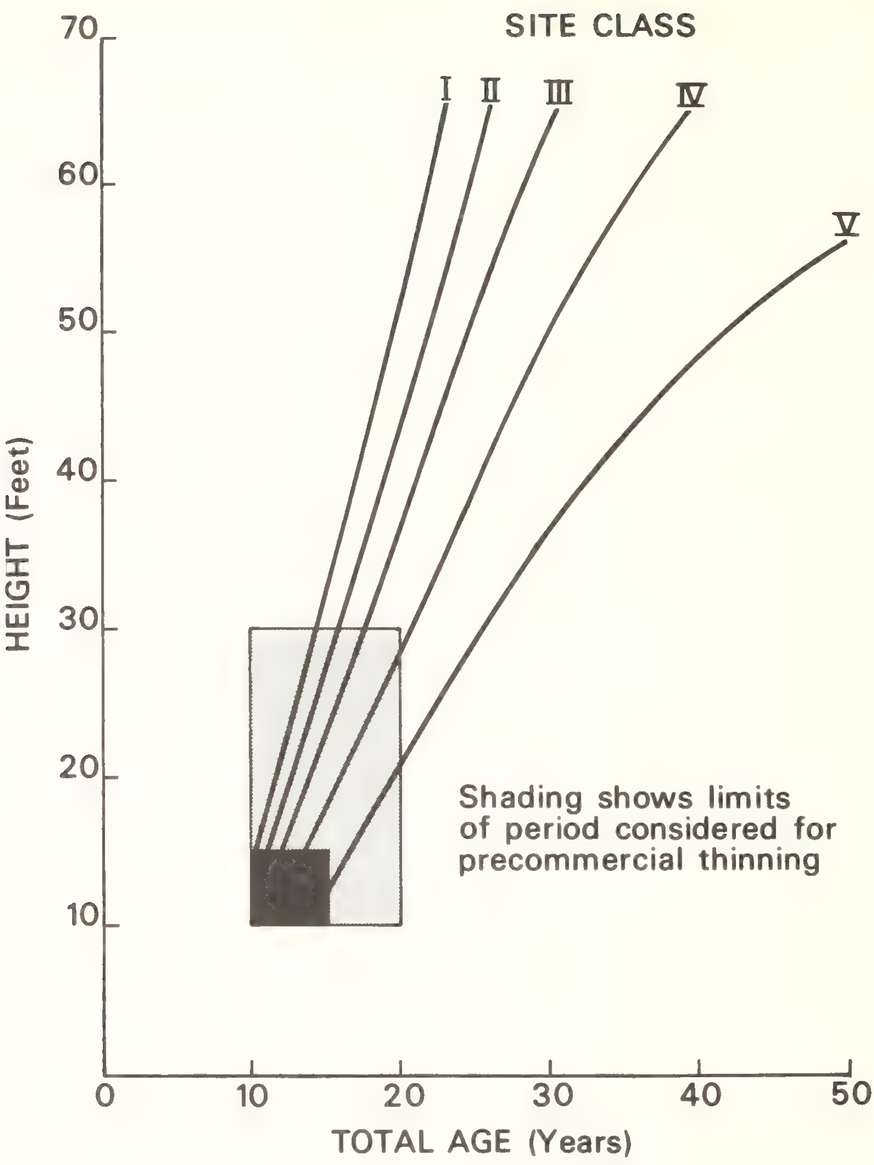

Figure 4.--*Relationship between age and height of dominant and codominant Douglas-fir trees, by site class.*

On the other hand, if commercial thinning required larger trees than in option III, gains from precommercial thinning would be even greater. Where delayed precommercial thinning might not be justified if 6-inch (15-cm) trees are considered merchantable, it might be justified if trees must have a d.b.h. of 8 inches (20 cm) or larger to be merchantable.

Percentage gains in mean annual increment (m.a.i.) of usable volume due to precommercial thinning are closely related to these gains in time and age at

Table 2.--*Estimated ages of Douglas-fir at first commercial thinning, for selected conditions*

Precommercial thinning (PCT) options and treatments	Site				
	I	II	III	IV	V
	- - - - - - - - - - - *Age (years)* - - - - - - - - - -				
Option I (400 8-inch trees):					
Unmanaged	27	31	36	47	66
Ideal PCT time	23	26	30	37	50
PCT at age 20	--	--	--	41	55
PCT at 30 feet	25	28	33	42	64
Option II (335 9-inch trees):					
Unmanaged	30	35	41	53	76
Ideal PCT time	24	28	32	40	55
PCT at age 20	--	--	--	44	60
PCT at 30 feet	26	30	36	45	69
Option III (290 10-inch trees):					
Unmanaged	32	38	45	59	86
Ideal PCT time	25	29	34	43	60
PCT at age 20	--	--	--	48	65
PCT at 30 feet	27	32	38	48	74

first commercial thinning; the ratio of percentage-gain to years-gained tends to increase with age at first commercial thinning.[6/] Thus, for any of these commercial thinning options, percentage gains from precommercial thinning within the above limits increase markedly with decreasing site quality. The resulting absolute gains in usable m.a.i. also increase with decreasing site quality--at least through site IV; gains on site V may be about equal to those on site IV.

If precommercial thinning is not done until leave trees are about 30 feet (9 m) tall, it will not be practical to create as uniform a stand as could be done with earlier thinning. Dominant and codominant trees will then have an average d.b.h. of about 4 inches (10 cm) or more, and some will be more than 25 percent larger than this average. When these trees are close to merchantable size, they should generally be retained in the stand until at least the first commercial thinning, unless they are wolf-trees.

[6/] This conclusion has been derived from both theoretical considerations and *preliminary* estimates of yields attainable with thinning.

CONCLUSION

Ideally, precommercial thinning should be done when leave trees are about 10 to 15 feet (3 to 5 m) tall and 10 to 15 years old. The spacing of residual trees should depend on how large the trees will be when the first commercial thinning will be made; the larger the trees at that time, the fewer should be left, as per the stocking guide. The thinning should create a uniform tree size.

If this ideal stage has passed, there are still worthwhile opportunities for precommercial thinning; but gains will be less. Gains from precommercial thinning in stands where leave trees are up to 20 years old or 30 feet (9 m) tall, whichever comes first, can still be quite substantial. The maximum age or tree size at which precommercial thinning is practical depends on several factors. Probably the most critical of these is the size that trees must attain before a commercial thinning will be made.

The need for precommercial thinning is greatest on poor-quality sites, where it may make the difference in whether or not a crop of merchantable trees is produced within an economic time frame. On better sites, a satisfactory crop can be produced without precommercial thinning.

☆ G.P.O.

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U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE

ABSTRACT

This paper describes four computer programs for the logging engineer's use in planning log harvesting by skyline systems. One program prepares terrain profile plots from maps mounted on a digitizer; the other programs prepare load-carrying capability and other information for single and multispan standing skylines and single span running skylines. In general, the three skyline programs prepare load paths, forces, and cable tension information from inputs of equipment specifications and anchoring geometry. Listings and explanations for all programs are included.

Keywords: Skyline logging, logging operations analysis/design, computer programs.

CONTENTS

INTRODUCTION

This paper presents four computer programs with specific application to skyline harvest unit layout: One program prepares terrain profiles from maps, and three programs express characteristics of load-carrying skylines.

The scope of this paper is limited to a simple and concise presentation of the programs without extensive interpretation of the information prepared by each. The mechanics of their use (i.e., details of input and output) are discussed thoroughly, but no attempt is made to explain the algorithms used.

GENERAL INFORMATION

The programs are written in the American Standard Code for Information Interchange (ASCII) BASIC language common to many computer systems. They were developed on a Hewlett-Packard 9830 desk-top calculator/plotter/digitizer system (fig. 1) at the Station's Forest Engineering Laboratory, Seattle, Washington.

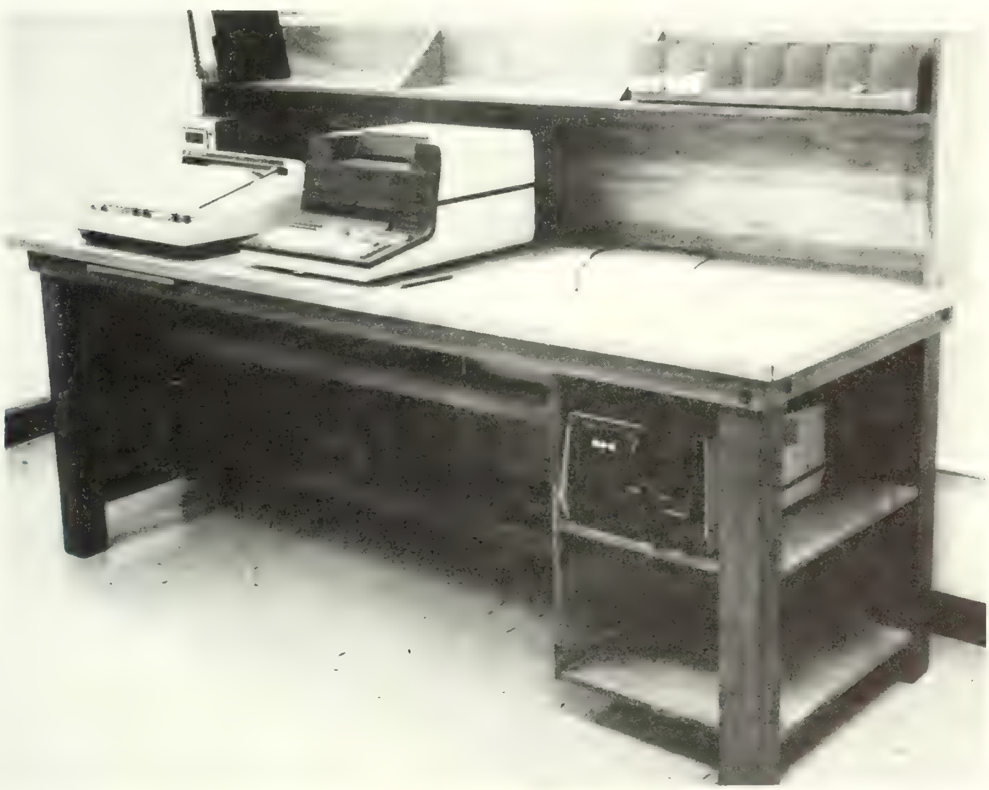


Figure 1.—Desk-top calculator system with digitizer, plotter, printer, and card reader.

The configuration of this system can vary depending on the optional features included. The minimum calculator system configuration required to run the programs is:

I. Profile program
- BASIC MODEL 30 calculator with 3520 bytes of Read/Write Memory
- Additional Read Only Memories
    - Plotter control
    - Extended I/O
- Plotter (9862A)
- Digitizer (9864A)
- Thermal page printer (9866A)

II. All skyline programs
- BASIC MODEL 30 calculator with (at least) 9000 bytes of Read/Write Memory
- Additional Read Only Memories
    - Plotter control
    - Extended I/O
    - String variable (this requirement could be eliminated)
- Plotter (9862A)
- Thermal page printer (9866A)

Although these programs were prepared on a particular computer system and some familiarity with the mechanics of its operation is presumed, they are not limited to it. The ASCII BASIC language is a common computer code, and the programs can be executed on many other facilities. A listing of each program is included for use on other systems.

SYSTEM OF UNITS

The programs presume the user is working with our traditional system of units. Length measurements are in feet or inches and forces or tensions, in pounds. However, the International System of Units (SI) could be accommodated. The user need only be consistent in the input and interpretation of output. The input and output label should be modified to eliminate confusion if other units will be used.

VISUAL PROMPTERS

One goal in the development of these programs was to integrate a large portion of their documentation into the programs themselves. Ideally we expected to produce programs that, while they were being run in the machine, would provide enough instructions to lead a user through their execution. The approach was to request keyboard or digitizer inputs by display of interrogatory statement or other printed messages. These are called "visual prompters" for input. Their meaning is important to an understanding of each program, and consequently, the explanation of program use will focus on definitions for the visual prompters, which are in the tables.

INITIALIZATION

These programs reside on one magnetic tape cassette. The first file on the tape contains programs which load into the special function keys and are important to the execution of other programs. Therefore, the first step in the use of these programs is

LOADKEY 1, EXECUTE .

This will load several programs and/or instructions into the special function keys. These are labeled on the special function card (fig. 2). Keys f_0 through f_4 are part of the profile program and will be discussed in that section. The key f_5 provides a message (see fig. 3) about plotter precautions; keys f_6 through f_9 are for loading each main program from the magnetic tape cassette. The tape cassette should be rewound after execution of any of these special functions to minimize the chance of damage to tapes.

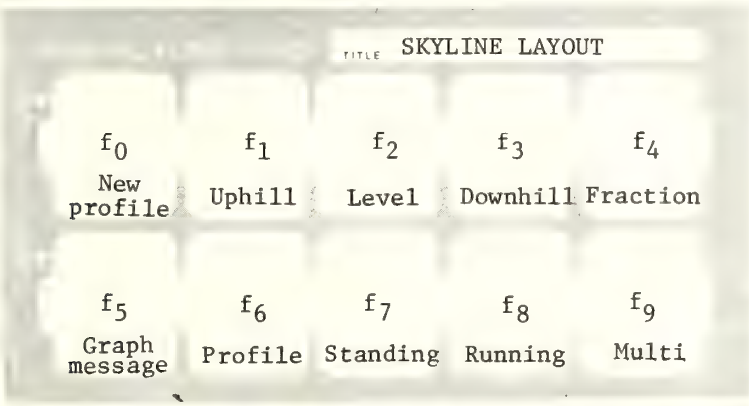


Figure 2.—Special function card for skyline layout program.

```
THE PROGRAMS IN THIS PACKAGE USE THE HP9862A PLOTTER.
THEREFORE THE USER MUST ESTABLISH GRAPH LIMITS ON THE
PLOTTER AND SUPPLY SCALE FACTORS TO THE HP9830 COMPUTER.
THE GRAPH LIMITS ARE SET MANUALLY AS EXPLAINED IN THE PLOTTER
DOCUMENT.  THE SCALE FACTORS ARE ENTERED INTO THE COMPUTER
DURING PROGRAM EXECUTION FOLLOWING THE VISUAL PROMPTERS:
               (HORIZONTAL GRAPH LIMITS(FEET)?)
AND            (VERTICAL GRAPH LIMITS(FEET)?) .
IT IS ALSO NECESSARY TO ESTABLISH THE PEN LOCATION FOR THE PLOTS
GENERATED BY EACH PROGRAM. THIS LOCATION IS MEASURED ON THE
PAPER WITH RESPECT TO THE LEFT GRAPH LIMIT WHICH IS REFERRED TO
AS THE ORIGIN.  EACH PROGRAM WILL REQUEST PEN LOCATION WITH
RESPECT TO THE ORIGIN AS IT REQUIRES IT.
```

Figure 3.—The "GRAPH MESSAGE" program on the f_5 key.

SKYLINE PROFILE COMPUTER/PLOTTER/DIGITIZER PROGRAM

This program prepares a terrain profile on the plotter from information on a topographic map mounted on the system's digitizer. The program also prints span and elevation information.

Description

The program is arranged as a main program and five subprograms recorded on the special function keys.

The main program establishes plot scale, records map scale and contour interval and also provides some operating instructions during execution in either the form of printed messages or requests for input (visual prompters) on the computer display.

The function key program on f_0 establishes plotter pen location and a number identification for the profile to be plotted, and calls for the coordinates of the first point on the profile.

The function key programs on f_1 through f_3 plot uphill, level, or downhill contours. Because a fractional contour is sometimes needed, a program is provided on f_4 to handle fractions of a contour interval.

User Instructions

The following example demonstrates the program operation. Figure 4 is a map contrived to demonstrate all features of the program. The profile shown in figure 5 was produced from the contour map of figure 4.

Preliminary steps:

1. Press STOP and END to prepare for loading a program.
2. Press function key f_6 (or LOAD 2, EXECUTE).
3. Adjust graph limits on plotter.
4. Mount map on digitizer surface.

Continue through entries in table 1 which relates the keyboard and digitizer inputs to the visual prompters on the computer display.

Output

This program prepares both plotted and printed output. The plotted results (fig. 5) present the profile of the terrain identified on the map. The horizontal distances and elevations are to the scale specified by the user.

The printed output is shown in figure 6. In addition to the initial entries for map scale and contour interval, the program prints some instructions to familiarize the user with the program operation; for each profile taken from a map, a tabulation of span and elevation for each digitized point is printed. The tabular entries are referenced to the first point in each series. Sections of the profile are labeled to identify uphill, downhill, or level terrain. These instructions are useful during operation of the program for the operator to check the accuracy of his work.

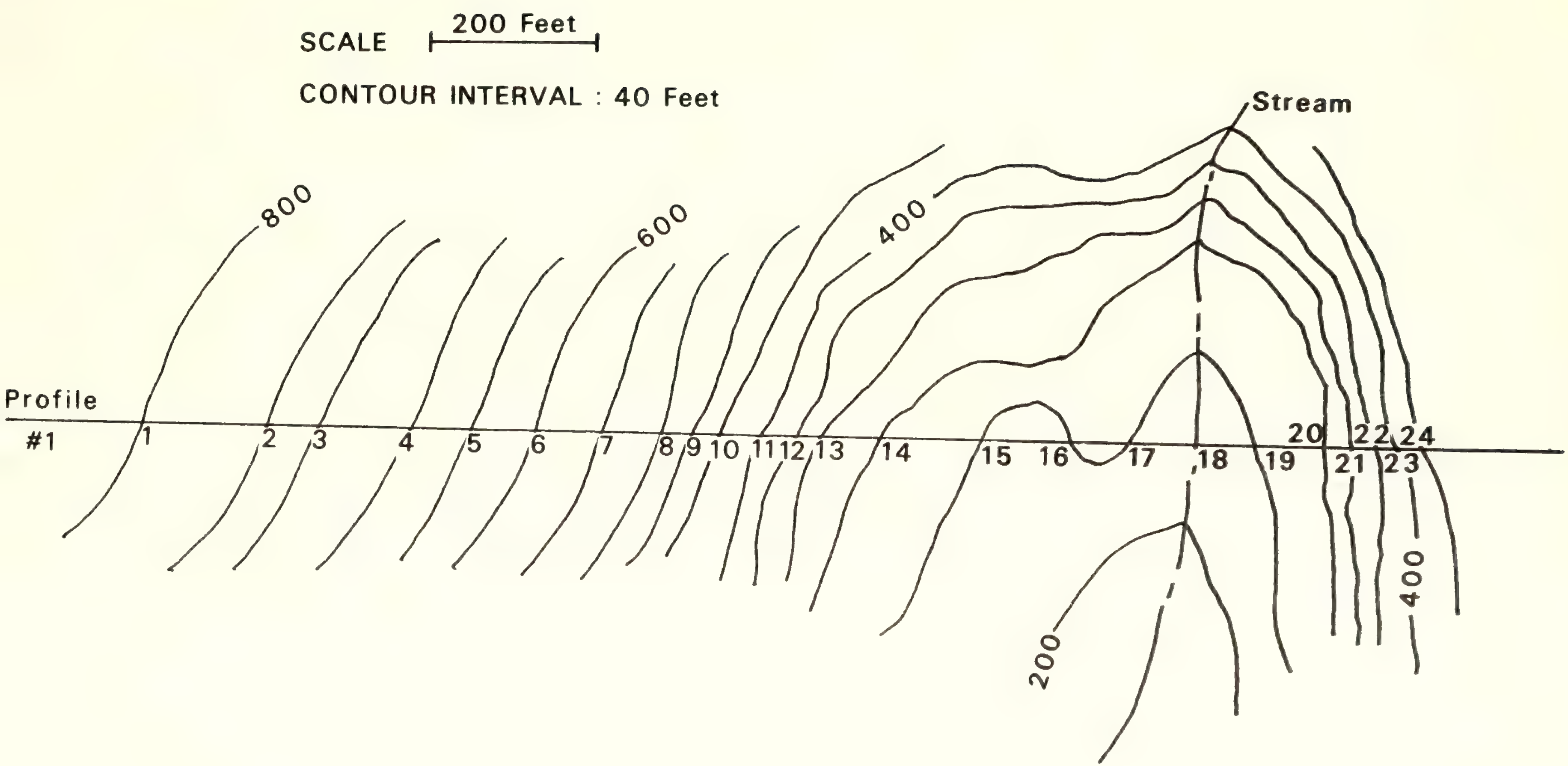


Figure 4.—Contour map.

Figure 5.—Terrain profile developed on plotter.

Table 1.--Input explanation for profile plot example

VISUAL PROMPTER ON DISPLAY	KEYBOARD RESPONSE	DESCRIPTION
HORIZONTAL GRAPH LIMITS (FEET)?	2000	Enters scale value for X-axis on plotter.
VERTICAL GRAPH LIMITS (FEET)?	1400	Enters scale value for Y-axis on plotter.
MAP SCALE (FEET/INCH)?	200	Enters scale of the map being used.
CONTOUR INTERVAL (FEET)?	40	Enters contour interval of the map being used.
PRESS - NEW PROFILE-FUNCTION KEY.	f_0	Executes program on function key f_0.
HORZ. DIST.: ORIGIN TO 1ST POINT?	100	Enters horizontal distance from origin of the graph paper to the first point on the terrain profile plot. The origin is taken as the lower left graph limits set by the operator.
ELEV. DIST.: ORIGIN TO 1ST POINT?	1100	Enters the vertical distance from the origin to the first point on the terrain profile plot.
PROFILE NUMBER?	1	Enters number of profile to be plotted.
DIGITIZE FIRST POINT AFTER BEEP.		(DIGITIZER RESPONSE): Set origin and digitize first point on the profile.
SELECT A SLOPE AND PROCEED.		
	f_3	Executes program on function key f_3 which anticipates downhill profile.
		(DIGITIZER RESPONSE): Digitize all downhill points (2 through 15).
	STOP	
	f_2	Executes program on function key f_2 which anticipates level profile.
		(DIGITIZER RESPONSE): Digitize level section (points 16 and 17).
	STOP	
	f_4	Executes program on function key f_4 which anticipates fractional contour interval.
FRACTION (+FOR UPHILL: -FOR DOWN)?	-.5	(DIGITIZER RESPONSE): Digitize bottom of stream (point 18).
	STOP	
	f_4	Executes f_4.
FRACTION (+FOR UPHILL: -FOR DOWN)?	+.5	(DIGITIZER RESPONSE): Digitize next contour (point 19).
	STOP	
	f_1	Executes program on function key f_1 which anticipates uphill profile.
		(DIGITIZER RESPONSE): Digitize remaining uphill points (points 20 and 24).
	STOP	

```
             ***PROGRAM TO ENTER AND PLOT PROFILE***

NOTE:GRAPH LIMITS MUST BE ESTABLISHED ON PLOTTER
MAP SCALE = 200 FEET PER INCH
CONTOUR INTERVAL = 40    FEET

   ***SOME INSTRUCTIONS ON OPERATING THE PROGRAM***
       THE OPERATOR HAS 5 FUNCTION KEYS AVAILABLE FOR
      CONTROL OF THE PROGRAM. THESE ARE
        F0:NEW PROFILE - PRESS AT START OF EACH NEW PROFILE.
        F1:UPHILL - USED WHEN DIGITIZING AN UPHILL SECTION.
        F2:LEVEL - USED WHEN DIGITIZING A LEVEL SECTION.
        F3:DOWNHILL - USED WHEN DIGITIZING A DOWNHILL SECTION.
        F4:FRACTIONAL - FOR INCREMENTING A FRACTION OF THE CONTOUR.

       THE RATE OF DIGITIZING IS CONTROLLED BY AN AUDIBLE
      BEEP. AFTER EACH BEEP DIGITIZE A PROFILE POINT.

       FOR EACH NEW PROFILE THE PEN MUST BE LOCATED A DISTANCE
      TO THE RIGHT AND [illegible] FROM THE LOWER LEFT GRAPH LIMIT.

       TO BEGIN A PROFILE PRESS FUNCTION KEY F0.


[illegible]
[illegible]                                   DOWNHILL SLOPE
[illegible]
                                              LEVEL SLOPE
[illegible]
                                              FRACTIONAL INCREMENT=-20
[illegible]
                                              FRACTIONAL INCREMENT= 20
[illegible]
                                              UPHILL SLOPE
[illegible]
```

Figure 6.—Printed output from profile program.

PROFILE PROGRAM

There are six programs (the main program and five subprograms) in the skyline profile computer/plotter/digitizer program. Each program is relatively simple and, because of the ASCII BASIC language, self-explanatory. We include the listings here for those who may want to examine the algorithms or execute the programs on another facility.

LISTING OF MAIN PROFILE PROGRAM

```
10 PRINT TAB[illegible] "***PROGRAM TO ENTER [illegible] PROF[illegible]"
20 PRINT TAB100"NOTE:GRAPH L[illegible] BE ESTABLISHED ON F[illegible]
30 DISP "HORIZONTAL GRAPH LIMITS [illegible]
40 INPUT G1
50 DISP "VERTICAL GRAPH LIMITS [illegible]
60 INPUT G2
70 SCALE 0,G1,0,G2
80 REM ROUTINE TO TAKE PROFI[illegible]
90 REM PROGRAM PRESUMES OPERATOR [illegible] GRAPH [illegible] TO [illegible]
100 FIXED 0
110 DISP "MAP SCALE(FEET/INCH)[illegible]
120 INPUT H
130 PRINT "MAP SCALE = "H"FEET PER [illegible]
140 DISP "CONTOUR INTERVAL(FEET)[illegible]
150 INPUT C
160 PRINT "CONTOUR INTERVAL [illegible]"C[illegible]
170 PRINT
180 PRINT TAB[illegible] "***SOME INSTRU[illegible] OPERATING THE PROGRAM***"
190 PRINT TAB9"THE OPERATOR HAS [illegible] AVAILABLE FOR
200 PRINT TAB8"CONTROL OF THE PROGRA[illegible] HERE ARE
210 PRINT TAB10"F0:NEW PROFILE - [illegible] START OF EACH NEW PROFILE."
220 PRINT TAB10"F1:UPHILL - USED [illegible] UPHILL SECTION."
230 PRINT TAB10"F2:LEVEL - USED WHEN [illegible] LEVEL SECTION."
240 PRINT TAB10"F3:DOWNHILL - USED [illegible] DIGITIZING [illegible] DOWNHILL SEC[illegible]
250 PRINT TAB10"F4:FRACTIONAL - FOR [illegible]MENTING A FRACTION OF THE [illegible]."
260 PRINT TAB100,TAB9"THE RATE OF [illegible] IS CONTROLLED BY AN [illegible]
270 PRINT TAB8"BEEP. AFTER EACH [illegible] DIGITIZE A PROFILE POINT."
280 PRINT TAB100,TAB9"FOR EACH NEW PROFILE THE [illegible] MUST BE LOCAT[illegible]
290 PRINT TAB8"TO THE RIGHT AND A [illegible]ANCE UP FROM THE LOWER LEFT [illegible]
300 PRINT TAB100,TAB9"TO BEGIN A [illegible] PRESS FUNCTION KEY F0."TAB[illegible]
310 DISP "GOTO -NEW PROFILE- FUNCT[illegible]
320 STOP
330 END
```

PROGRAM on f_0 KEY

```
10 [illegible]
20 DIM [illegible]
30 INPUT [illegible]
40 DISP [illegible]
50 INPUT [illegible]
60 [illegible]
70 [illegible]
80 [illegible]
90 DISP [illegible]
100 INPUT [illegible]
110 [illegible]
120 [illegible]
130 [illegible]
140 [illegible]
150 [illegible]
160 [illegible] DATA FROM PTI
170 [illegible]
180 [illegible]
190 [illegible]
200 ENTER [illegible]
210 [illegible]
220 [illegible]
230 [illegible]
240 [illegible]
250 END
```

PROGRAM on f_1 KEY

```
10 [illegible]
20 [illegible]
30 [illegible]
40 [illegible]
50 [illegible]
60 [illegible]
70 [illegible]
80 [illegible]
90 [illegible]
100 [illegible]
110 [illegible]
120 [illegible]
130 [illegible]
140 [illegible]
150 [illegible]
160 [illegible]
170 END
```

PROGRAM on f_2 KEY

```
10 A1=6
20 PRINT TAB(10"LEVEL SLOPE"
30 WRITE (9,*)
40 ENTER (9,*)X2,Y2
50 N1=N1+1
60 X=X2-X1
70 Y=Y2-Y1
80 S=SQR(X*X+Y*Y)*H
90 S1=S1+S
100 E1=E1+A1*C
110 E=E1-E0
120 PRINT N1,S1,E
130 PLOT S1,E,2
140 X1=X2
150 Y1=Y2
160 GOTO 40
170 END
```

PROGRAM on f_3 KEY

```
10 A1=-1
20 PRINT TAB(10"DOWNHILL SLOPE"
30 WRITE (9,*)
40 ENTER (9,*)X2,Y2
50 N1=N1+1
60 X=X2-X1
70 Y=Y2-Y1
80 S=SQR(X*X+Y*Y)*H
90 S1=S1+S
100 E1=E1+A1*C
110 E=E1-E0
120 PRINT N1,S1,E
130 PLOT S1,E,2
140 X1=X2
150 Y1=Y2
160 GOTO 40
170 END
```

PROGRAM on f_4 KEY

```
10 DISP "[illegible]"
20 INPUT A1
30 B1=A1*C
40 PRINT TAB(10"FRACTIONAL [illegible]"
50 WRITE (9,*)
60 ENTER (9,*)X2,Y2
70 N1=N1+1
80 X=X2-X1
90 Y=Y2-Y1
100 S=SQR(X*X+Y*Y)*H
110 S1=S1+S
120 E1=E1+A1*C
130 E=E1-E0
140 PRINT N1,S1,E
150 PLOT S1,E,2
160 X1=X2
170 Y1=Y2
180 GOTO 50
190 END
```

SKYLINE PROGRAMS--GENERAL

There are three skyline programs--standing, running, and multispan. Organization and nomenclature are consistent for each program and can be discussed in general terms.

The primary purpose of each program is to develop a load path on the plotter. This load path is compared usually with a terrain profile which may have been generated by the profile program discussed in the previous section. It is important to recognize, however, that the profile may come from any source. The skyline programs operate independently of the terrain. They depend on the operator to describe plot scales and anchor point locations to properly aline the load paths with the profiles. The nomenclature is shown in figure 7.

The instructions for operating each program are an integral part of the program. They rely on the visual prompters that appear during program execution. Therefore, the format used to discuss program operation is the tabular arrangement of visual prompters with definitions and the numerical responses that will lead a user through an example.

The discussion of output is based on the results of the numerical example presented. These discussions describe the information provided by the program; but again, they do not purport to suggest the correct interpretation. Of course, the output information supports the skyline engineering layout task, but it is beyond the scope of this paper to discuss these activities extensively.

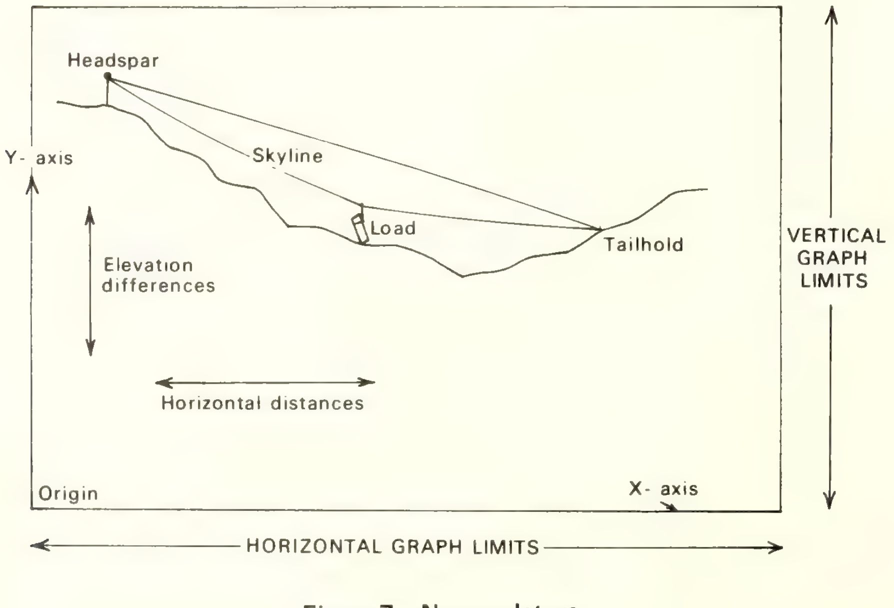


Figure 7.—Nomenclature.

SINGLE SPAN TIGHT LINE AND SLACKLINE LOAD PATH PROGRAM

This program determines the tensions, loads, and deflections of a single span standing skyline cable configuration (fig. 8). The system consists of a skyline suspended between a headspar and tailhold and a main line which moves a load along the skyline toward the headspar. In two sections of the program ("Equipment Description" and Geometry Description" in table 2), the sizes and relative location of anchoring points of skyline and main line are entered as input. With this information, the program can compute either the load that can be supported at any point (trial load section), or the tensions and deflection resulting from a given line length and load (load path section).

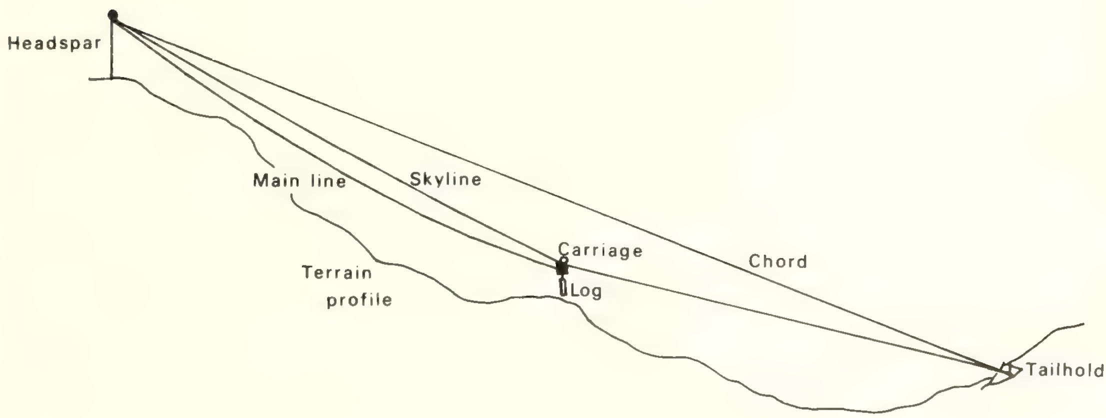


Figure 8.—Single span standing skyline.

User Instructions

The following example demonstrates use of this program: First, load file 1 (i.e., LOADKEY 1, EXECUTE), then continue:

1. Press STOP and END to prepare for loading the program.

2. Press function key f_7 (or LOAD 3, EXECUTE).

3. Adjust graph limits on plotter.

4. Continue with the procedure outlined in table 2 by responding to the visual prompters with the numerical or alphanumeric entries indicated in the middle column. The DESCRIPTIONS should be read for an understanding of the process.

Table 2.--Input explanation for standing skyline example

VISUAL PROMPTER ON DISPLAY	KEYBOARD RESPONSE	DESCRIPTION
HORIZONTAL GRAPH LIMITS (FEET)?	2000	Enters scale value for X-axis on plotter.
VERTICAL GRAPH LIMITS (FEET)?	1400	Enters scale value for Y-axis on plotter.
Equipment description		
SKYLINE SIZE (LB/FOOT)?	2.89	Enters weight per foot of skyline.
SKYLINE WORKING TENSION (LB)?	53300	Enters allowable working tension of skyline.
MAIN LINE SIZE (LB/FOOT)?	1.85	Enters weight per foot of main line.
MAIN LINE WORKING TENSION (LB)?	34500	Enters allowable working tension of main line.
Geometry description		
CORRIDOR NUMBER?	1	Enters number to identify skyline corridor.
HORZ. DIST.: HEADSPAR TO TAILHOLD?	1500	Enters skyline span.
ELEV. DIFF.: HEADSPAR TO TAILHOLD?	500	Enters vertical anchor point separation from top of headspar down to top of tailhold.
Trial load section		
HORZ. DIST.: HEADSPAR TO LOAD?	600	Enters horizontal distance to first trial load location.
ELEV. DIFF.: HEADSPAR TO LOAD?	350	Enters vertical distance from top of headspar down to carriage location for first trial.
HORZ. DIST.: HEADSPAR TO LOAD?	1200	Enters horizontal distance to second trial load location.
ELEV. DIFF.: HEADSPAR TO LOAD?	600	Enters vertical distance from top of headspar down to carriage location for second trial.
HORZ. DIST.: HEADSPAR TO LOAD?	0	Causes program control to branch to the load path section of program.
Load path section		
HORZ. DIST.: ORIGIN TO HEADSPAR?	100	Enters horizontal distance from origin to the top of the headspar. The origin is the lower left graph limit set by the operator.
ELEV. DIFF.: ORIGIN TO HEADSPAR?	1200	Enters vertical distance from origin to top of headspar.
TENSION DIAGNOSTIC REQUIRED?	NO	Provides some diagnostics about overstress if desired. If response is no, a plot of the load path is made automatically.
NEW LOAD PATH?	YES	Provides an opportunity to compute a load path for another load and line length.
LOAD?	13000	Enters load to be used for new load path.
LINE LENGTH?	1594	Enters the unstretched line length to be used for supporting the trial load.
TENSION DIAGNOSTIC REQUIRED?	YES	Provides diagnostics about line overstress.
DO YOU WANT A PLOT?	YES	Provides a plot of load path.
NEW LOAD PATH?	NO	Branches out of load path section.
NEW ANCHORING OR CORRIDOR?	NO	Terminates execution.

Output

This program prepares both plotted and printed output. The plotted results (fig. 9) show the load path of the point of contact between the carriage and the skyline. Two paths are shown. Each path represents the trajectory of a point on the carriage support sheave as it moves over the fixed length of skyline and deflects under the load. The stretch of the skyline due to variable tensions is accounted for. The path is composed of nine points in the span and purposely does not include the anchor points.

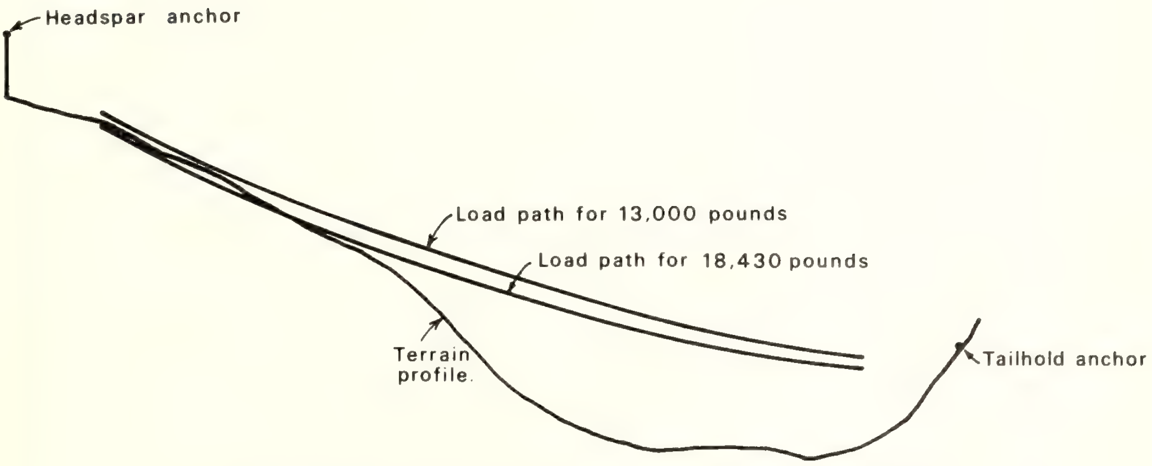


Figure 9.—Standing skyline plotted results (profile from fig. 5).

Figure 10 shows a sample of the printed output which summarizes input information and the tensions, line lengths, and forces in addition to the coordinates of points on the load path. Part A represents information that would be prepared while examining individual points in the skyline span for load capability. This part of the program, which provides load and line length from specified deflections, could be used to assess the capabilities of slack skyline. Part B, which gives the deflections and tensions associated with a fixed load and line length, could be used to investigate the potential for a tight skyline configuration.

```
***STANDING SKYLINE PROGRAM***
SALE IDENTIFICATION- EXAMPLE #2
     EQUIPMENT DESCRIPTION.
          SKYLINE SIZE [illegible]   POUNDS PER FOOT
          ALLOWABLE WORKING TENSION FOR SKYLINE 53300   POUNDS
          MAIN LINE SIZE [illegible]   POUNDS PER FOOT
          MAIN LINE ALLOWABLE WORKING TENSION= 34500   POUNDS


 CORRIDOR NUMBER  1
   HORIZONTAL DISTANCE FROM HEADSPAR TO TAILHOLD= 1500    FEET
   ELEVATION DIFFERENCE FROM HEADSPAR TO TAILHOLD= 500  FEET

 --PART A : TRIAL LOAD [illegible] DEFLECTIONS.
   TRIAL LOAD LOCATED AT [illegible] ELEVATION FROM HEADSPAR OF 350
        THE WEIGHT OF THE CARRIAGE PLUS LOAD [illegible]   POUNDS
        LENGTH OF THE SKYLINE BETWEEN SUPPORTS 1604.283   FEET

   TRIAL LOAD LOCATED AT [illegible]   WITH ELEVATION FROM HEADSPAR OF 600
        THE WEIGHT OF THE CARRIAGE PLUS LOAD 377[illegible]   POUNDS
        LENGTH OF THE SKYLINE BETWEEN SUPPORTS 1655.152   FEET


 --PART B : LOAD PATH [illegible] FOR LOAD OF [illegible]
            POUNDS AND AN UNSTRETCHED LINE LENGTH OF 1604.283   FEET.
  -DIST. HEADSPAR TO LOAD-             LINE TENSIONS-
   HORZ.      VERT.          MAIN LINE      SKYLINE AT HEADSPAR
   150        146            10[illegible]  314[illegible]
   300        [illegible]    8[illegible]   426[illegible]
   450        [illegible]41  [illegible]    494[illegible]
   600        [illegible]    7004           534[illegible]  *
   750        [illegible]    6[illegible]   55[illegible]   *
   900        [illegible]    57[illegible]  54[illegible]   *
   1050       [illegible]    5[illegible]   522[illegible]
   1200       [illegible]16  [illegible]    47[illegible]55
   1350       [illegible]41  2[illegible]   37[illegible]
   1500            END OF SPAN

 --PART B : LOAD PATH [illegible] FOR LOAD OF 1[illegible]000
            POUNDS AND AN UNSTRETCHED LINE LENGTH OF 1594.000   FEET.
  -DIST. HEADSPAR TO LOAD-             LINE TENSIONS-
   HORZ.      VERT.          MAIN LINE      SKYLINE AT HEADSPAR
   150        121            [illegible]    316[illegible]
   300        1[illegible]5  5[illegible]   [illegible]
   450        [illegible]    5[illegible]   480[illegible]
   600        [illegible]15  [illegible]    52095
   750        [illegible]    4[illegible]   53549   *
   900        414            [illegible]    53309   *
   1050       455            4033           5057[illegible]
   1200       439            33[illegible]  45760
   1350       514            26[illegible]  36651
   1500            END OF SPAN
    DIAGNOSTIC OUTPUT ON SKYLINE OVERSTRESS
          *LOCATIONS WHERE SAFE SKYLINE TENSIONS WERE EXCEEDED

          DIST. OUT         T-MAX AT         LOAD WHICH WOULD
                            LEFT ANCHOR      PREVENT OVERSTRESS
            750             555[illegible]   12923
            900             5[illegible]     12937
```


Figure 10.—Printed output from standing skyline program.

LISTING OF THE STANDING SKYLINE PROGRAM

```
10 REM PROGRAM TO AID IN THE [illegible] STANDING [illegible]LINES.
20 DIM T$[30]
30 PRINT TAB100"NOTE:GRAPH LIMITS [illegible] ON [illegible]
40 DISP "HORIZONTAL GRAPH LIMITS(FEET)";
50 INPUT G1
60 DISP "VERTICAL GRAPH LIMITS(FEET)";
70 INPUT G2
80 SCALE 0,G1,0,G2
90 PLOT 0,0,1
100 PRINT TAB20"***STANDING SKYLINE PROGRAM***"
110 DISP "SALE IDENTIFICATION";
120 INPUT T$
130 PRINT "SALE IDENTIFICATION ";T$
140 REM***INPUT***
150 PRINT TAB9"EQUIPMENT DESCRIPTION"
160 DISP "SKYLINE SIZE(LB/FOOT)";
170 INPUT W1
180 PRINT TAB15"SKYLINE SIZE"W1"POUNDS PER FOOT"
190 DISP "SKYLINE WORKING TENSION(LB)";
200 INPUT T
210 PRINT TAB15"ALLOWABLE WORKING TENSION FOR SKYLINE "T"POUNDS"
220 DISP "MAIN LINE SIZE(LB/FOOT)";
230 INPUT W3
240 PRINT TAB15"MAIN LINE SIZE"W3"POUNDS PER FOOT"
250 DISP "MAIN LINE WORKING TENSION(LB)";
260 INPUT T5
270 PRINT TAB15"MAIN LINE ALLOWABLE WORKING TENSION "T5"POUNDS"
280 PRINT TAB100
290 DISP "CORRIDOR NUMBER";
300 INPUT T$
310 PRINT " CORRIDOR NUMBER- ";T$
320 DISP "HORZ.DIST.:HEADSPAR TO TAILHOLD";
330 INPUT L
340 PRINT TAB4"HORIZONTAL DISTANCE FROM HEADSPAR TO TAILHOLD="L"FEET"
350 DISP "ELEV.DIFF.:HEADSPAR TO TAILHOLD";
360 INPUT H
370 IF H>0 THEN 400
380 DISP "MUST BE POSITIVE-I.E.DOWNHILL";
390 INPUT H
400 PRINT TAB4"ELEVATION DIFFERENCE FROM HEADSPAR TO TAILHOLD="H"FEET"
410 E0=W=1000000
420 E1=3500000
430 REM***TRIALS OF LOAD POINTS.
440 PRINT TAB100;" ---PART A : TRIAL LOAD LOCATIONS AND DEFLECTIONS.
450 DISP "HORZ.DIST.:HEADSPAR TO LOAD";
460 INPUT D1
470 IF D1=0 THEN [illegible]30
480 DISP "ELEV.DIFF.:HEADSPAR TO LOAD";
490 INPUT Y1
```

```
500 FIXED 0
510 PRINT TAB[illegible]"TRIAL LOAD [illegible]   WITH ELEVATION FROM HEADSPAR OF"Y1
520 N=0
530 GOSUB 1440
540 S=S1+S2
550 PRINT TAB10"THE WEIGHT OF THE CARRIAGE PLUS LOAD"F1;"POUNDS"
560 FIXED 3
570 IF F1[illegible]0 THEN 5[illegible]0
580 PRINT "[illegible] NOT ALLOWED. TRY NEW LOAD ARRANGEMEN
590 PRINT TAB10"LENGTH OF THE [illegible] BETWEEN SUPPORTS"S;"FEET"
600 PRINT
610 REM***GET MINIMUM LOAD AND [illegible].
620 W0=F1
630 IF W0[illegible]W THEN 670
640 IF F1[illegible]0 THEN 710
650 S0=S
660 W=W0
670 Y2=[illegible]
680 E2=(Y1[illegible]
690 IF E2[illegible]E0 THEN 710
700 E0=E2
710 GOTO 450
720 REM*[illegible] PROGRAM*************************
730 I=J=K=[illegible]
740 F1[illegible]W
750 S=S0
760 FIXED 0
770 PRINT TAB[illegible]"[illegible] FOR LOAD OF"F1
780 FIXED 3
790 PRINT TAB[illegible]" POUNDS [illegible] LINE LENGTH OF"S"FEET."
800 DISP "HORZ.DIST.[illegible]
810 INPUT X0
820 DISP "ELEV.DIFF.[illegible]
830 INPUT Y0
840 OFFSET X0,Y0
850 PLOT 0,0,1
860 PRINT "   [illegible]DIST.[illegible]HEADSPAR[illegible]          -LINE TENSIONS-"
870 PRINT "      HORZ.        VERT.   [illegible] LINE","S[illegible]LINE AT HEADSPAR"
880 N=N+1
890 FIXED 0
900 D1=N/10*[illegible]
910 IF N=10 THEN 1340
920 Y1=D1*H/L+L*E0*3.4
930 Y4=Y1
940 GOSUB 1440
950 S4=S-(S1+S2)
960 IF ABS(S4)<S/10000 THEN 1000
970 Y5=Y1+L*E0/2
980 Y1=Y5
990 GOSUB 1020
```

```
1000 K=K+1
1010 M[K]=D1
1020 N[K]=Y1
1030 IF INT(H0)<0 THEN 1100
1040 T4=T1+W1*Y1
1050 T6=T3+W3*Y1
1060 IF INT(T4)>T THEN 1120
1070 IF INT(T6)>T5 THEN 1230
1080 PRINT TAB5,D1,Y1,T6,T4
1090 GOTO 880
1100 PRINT TAB5,D1,Y[illegible]"H0-"H[illegible] BACK RE[illegible]"
1110 GOTO 880
1120 PRINT TAB5,D1,Y1,T6,T4"*"
1130 I8=1
1140 K1=R2*(Y1-H)/(2*(L-D1))
1150 K2=((Y1-H)/(L-D1))↑2+1
1160 H2=(K1+SQR(K1↑2-K2*([illegible]R2[illegible]W1*Y1[illegible]2[illegible]K2
1170 F2=H2*((Y1/D1)+(Y1-H)/(L-D1)[illegible]F[illegible]F2+R3/[illegible]
1180 I=I+1
1190 A[I]=D1
1200 B[I]=T4
1210 C[I]=F2
1220 GOTO 880
1230 PRINT TAB5,D1,Y1,T6"**",T4
1240 I9=1
1250 B7=R3/2*(Y1/D1)
1260 B8=SQR(B7↑2-(1+(Y1/D1)↑2)*[illegible]T5[illegible]
1270 H4=(B7+B8)/(1+(Y1/D1)↑2)
1280 F3=F1*H4/H3
1290 J=J+1
1300 E[J]=D1
1310 F[J]=T6
1320 G[J]=F3
1330 GOTO 880
1340 PRINT TAB5,L,TAB20"END OF [illegible]"
1350 IF (I8+I9)=0 THEN 1[illegible]
1360 DISP "TENSION DIAGNOSTICS RE[illegible]";
1370 INPUT T$
1380 IF T$="NO" THEN 1430
1390 GOSUB 2070
1400 DISP "DO YOU WANT A PLOT";
1410 INPUT T$
1420 IF T$="NO" THEN 2360
1430 GOTO 2270
1440 REM***SUB1***DETERMINES RELATIONS[illegible] BETWEEN GEOMETRY,LOAD,AND [illegible]
1450 R1=SQR(D1↑2+Y1↑2)*W1
1460 R2=SQR((L-D1)↑2+(Y1-H)↑2)*W1
1470 R3=SQR(D1↑2+Y1↑2)*W3
1480 B1=R1*Y1/2/D1
1490 B2=(Y1/D1)↑2+1
```

```
1500 IF N#0 THEN 1550
1510 B4=R2/2+(Y1-H)/(L-D1)
1520 B5=((Y1-H)/(L-D1))↑2+[illegible]
1530 GOSUB 1670
1540 GOTO 1560
1550 GOSUB 1740
1560 D0=D1*W1/2/H1
1570 A2=(EXP(D0)-EXP(-D0))/2
1580 A3=SQR(Y1↑2+((2*H1/W1)*A2)↑2)
1590 D3=1+1/3*D0↑2-1/45*D0↑4+[illegible]/945*[illegible]
1600 S1=A3-H1/(E1*W1↑2)*[illegible]*(1+(Y1/A3)↑2)*D3/(D1/A3)↑2)*D1/2
1610 D0=(L-D1)*W1/2/H2
1620 A5=(EXP(D0)-EXP(-D0))/2
1630 A6=SQR((Y1-H)↑2+((2*H2/W1)*A5)↑2)
1640 D3=1+1/3*D0↑2-1/45*D0↑4+[illegible]/945*[illegible]
1650 S2=A6-H2/(E1*W1↑2)*[illegible]*(1+((Y1-H)/A6)↑2)*D3/((L-D1)/A6)↑2)*(L-D1)/2
1660 RETURN
1670 REM***SUB2***DETERMINES [illegible] GEOMETRY AND TENSION.
1680 B3=(R1/2)↑2-(T-W1*Y1)↑2
1690 H1=(B1+SQR(B1↑2-B2*B3))/B2
1700 B6=(R2/2)↑2-(T-W1*Y1)↑2
1710 H2=(B4+SQR(B4↑2-B5*B6))/B5
1720 F1=H2*(Y1/D1+(Y1-H)/(L-D1))-[illegible]*R2/2
1730 RETURN
1740 REM***SUB3***DETERMINES TENSION FROM LOAD AND GEOMETRY.
1750 H2=(F1+(R1+R2+R3)/2)/(Y1/D1+(Y1-H)/(L-D1))
1760 T1=SQR((H2*(Y1-H)/(L-D1)-R2/2)↑2+H2↑2)
1770 B3=(R1/2)↑2-T1↑2
1780 H1=(B1+SQR(B1↑2-B2*B3))/B2
1790 H3=H2-H1
1800 T3=SQR(H3↑2+B2-H3*R3*Y1/D1+[illegible])
1810 RETURN
1820 REM***SUB4***ITERATION FOR [illegible] WITH SECANT METHOD
1830 N9=1
1840 GOSUB 1440
1850 S5=S0-(S1+S2)
1860 IF ABS(S5)<0.2 THEN 2010
1870 D9=(Y5-Y4)*S5/(S5-S4)
1880 Y4=Y5
1890 Y5=Y5-D9
1900 IF Y5>0 THEN 1950
1910 N9=N9+1
1920 Y5=Y5+D9
1930 D9=D9/2
1940 GOTO 1890
1950 Y1=Y5
1960 S4=S5
1970 DISP "POINT"N;"ITERATION"N9
1980 N9=N9+1
1990 IF N9<20 THEN 1840
```

```
2000 PRINT "CONVERGENCE PROBLEM IN DEFLECTION ROUTINE AT H1="H1
2010 RETURN
2020 REM***SUB5***PRINTS OUT DIAGNOSTICS ABOUT OVERTENSION UPON REQUEST
2030 IF I8=0 THEN 2140
2040 I7=1
2050 PRINT TAB7"DIAGNOSTIC OUTPUT ON SKYLINE OVERSTRESS"
2060 PRINT TAB18;"*LOCATIONS WHERE SAFE SKYLINE TENSIONS WERE EXCEEDED"
2070 PRINT
2080 PRINT TAB15;"DIST. OUT","T-MAX AT","LOAD WHICH WOULD"
2090 PRINT TAB30"LEFT ANCHOR","PREVENT OVERSTRESS"
2100 Z=I
2110 FOR I=1 TO Z
2120 PRINT TAB15,A[I],B[I],C[I]
2130 NEXT I
2140 IF I9=0 THEN 2250
2150 I7=1
2160 PRINT TAB7"DIAGNOSTIC OUTPUT FOR MAIN LINE OVERSTRESS"
2170 PRINT TAB17;"**LOCATIONS WHERE SAFE MAIN LINE TENSIONS WERE EXCEEDED"
2180 PRINT
2190 PRINT TAB15,"DIST. OUT","T-MAX AT","LOAD WHICH WOULD"
2200 PRINT TAB30"LEFT ANCHOR","PREVENT OVERSTRESS."
2210 V=J
2220 FOR J=1 TO V
2230 PRINT TAB15,E[J],F[J],G[J]
2240 NEXT J
2250 PRINT TAB100,TAB100
2260 RETURN
2270 REM***PLOT OF LOAD PATH
2280 PLOT 0,0,-2
2290 PLOT 0,0,1
2300 FOR K=1 TO 9
2310 PLOT M[K],-N[K],-2
2320 NEXT K
2330 PLOT L,-H,1
2340 PLOT L,-H,2
2350 PEN
2360 DISP "NEW LOAD PATH";
2370 INPUT T$
2380 IF T$#"YES" THEN 2510
2390 DISP "LOAD";
2400 INPUT W
2410 DISP "LINE LENGTH";
2420 INPUT S0
2430 I=J=K=I7=I8=I9=N=0
2440 F1=W
2450 S=S0
2460 FIXED 0
2470 PRINT TAB100," ---PART B : LOAD PATH COORDINATES FOR LOAD OF"F;
2480 FIXED 3
2490 PRINT TAB11" POUNDS AND AN UNSTRETCHED LINE LENGTH OF"S"FEET."
2500 GOTO 850
2510 DISP "NEW ANCHORING OR CORRIDOR";
2520 INPUT T$
2530 IF T$#"NO" THEN 280
2540 END
```

RUNNING SKYLINE LOAD PATH PROGRAM

This program determines tensions, loads, and deflections of a running skyline cable configuration (fig. 11). The system consists of a haulback, which serves also as the skyline, and a main line and slack-pulling line. In two sections of the program ("Equipment Description" and "Geometry Description" in table 3), the sizes and relative location of anchoring points for these lines are entered as input. The operating tension of the haulback, which is assumed to be nearly constant during yarding, is entered also. With this information, the program can compute either the path of a load held free of the ground or the path of a load with one end supported by the ground. For the log-dragging situation, the user must also specify the angle of drag (see fig. 12) and the friction coefficient between the log and the ground. The information provided by the program can be used in judging the capabilities of the running skyline.

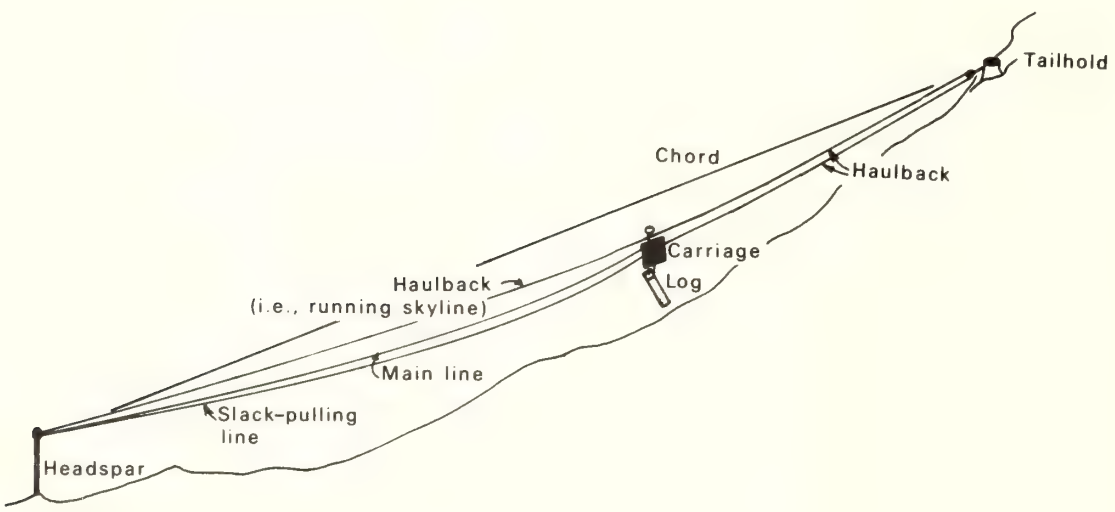


Figure 11.—Running skyline.

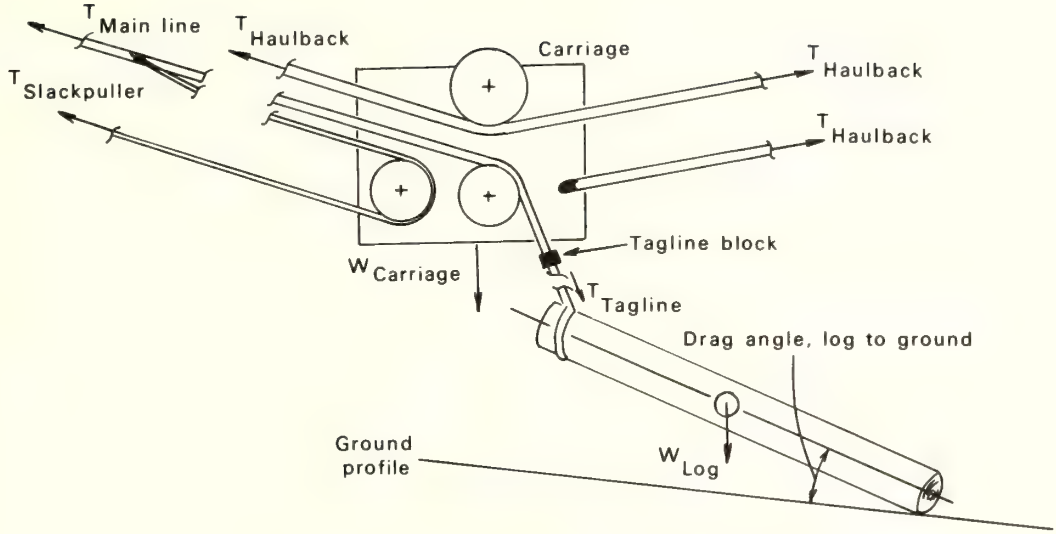


Figure 12.—Running skyline carriage configuration.

User Instructions

The following example demonstrates use of this program. The first step is to load file 1 (i.e., LOADKEY 1, EXECUTE) and then continue through the following procedure:

1. Press STOP and END to prepare for loading the program.
2. Press function key f_8 (or LOAD 4, EXECUTE).
3. Adjust graph limits on plotter.
4. Continue with the procedure outlined in table 3 by responding to the visual prompters with the numerical or alphanumeric entries indicated in the middle column. The DESCRIPTIONS should be read for an understanding of the process.

Table 3.--Input explanation for running skyline example

VISUAL PROMPTER ON DISPLAY	KEYBOARD RESPONSE	DESCRIPTION
HORIZONTAL GRAPH LIMITS (FEET)?	2000	Enters scale value for X-axis on plotter.
VERTICAL GRAPH LIMITS (FEET)?	1400	Enters scale value for Y-axis on plotter.
<u>Equipment description</u>		
HAULBACK WEIGHT (LB/FOOT)?	1.04	Enters weight per foot of the haulback (i.e., the running skyline).
HAULBACK WORKING TENSION (LB)?	19600	Enters the tension held in the haulback line by the interlock mechanism.
MAIN + SLACKLINE WEIGHT (LB/FOOT)?	1.44	Enters the combined weight of the main and slack-pulling lines.
CARRIAGE WEIGHT (LB)?	1200	Enters the carriage weight.
<u>Geometry description</u>		
CORRIDOR NUMBER?	3	Enters number to identify skyline corridor.
HORZ. DIST.: HEADSPAR TO TAILHOLD?	1500	Enters skyline span.
ELEV. DIFF.: HEADSPAR TO TAILHOLD?	-600	Enters vertical anchor point separation from top of headspar down to top of tailhold.
<u>Load path section</u>		
HORZ. DIST.: ORIGIN TO HEADSPAR?	100	Enters horizontal distance from origin to the top of the headspar. The origin is the lower left graph limits set by the operator.
ELEV. DIFF.: ORIGIN TO HEADSPAR?	400	Enters vertical distance from origin to top of the headspar.
ANTICIPATED LOAD SIZE (POUNDS)?	10000	Enters trial load value.
LOG DRAGGING (RESPOND YES OR NO)?	NO	Indicates the load path will be computed for the load suspended free of the ground.
DO YOU WANT A PLOT?	YES	Will provide a plot of the load path.
TRY ANOTHER PAYLOAD?	YES	Provides an opportunity to compute a load path for another load arrangement.
ANTICIPATED LOAD SIZE (POUNDS)?	10000	Enters trial load value.
LOG DRAGGING (RESPOND YES OR NO)?	YES	Indicates the load path will be computed for one end of the log dragging on the ground.
DRAG ANGLE, LOG TO GROUND (DEGS.)?	20	The angle the log makes with the ground in degrees (see fig. 12).
COEFFICIENT OF FRICTION?	0.6	The coefficient of friction between the ground and the dragging log.
DO YOU WANT A PLOT?	YES	Will provide a plot of the load path.
TRY ANOTHER PAYLOAD?	NO	Terminates computation on this configuration.

Output

This program prepares both plotted and printed output. The plotted results (fig. 13) show the load path of the point of contact between the haulback (running skyline) and the carriage. Two paths are shown in figure 13, one for a log dragging situation, the other for the log load carried free of the ground. Each represents a trajectory of the carriage-skyline contact point as the load is moved from tailhold to headspar.

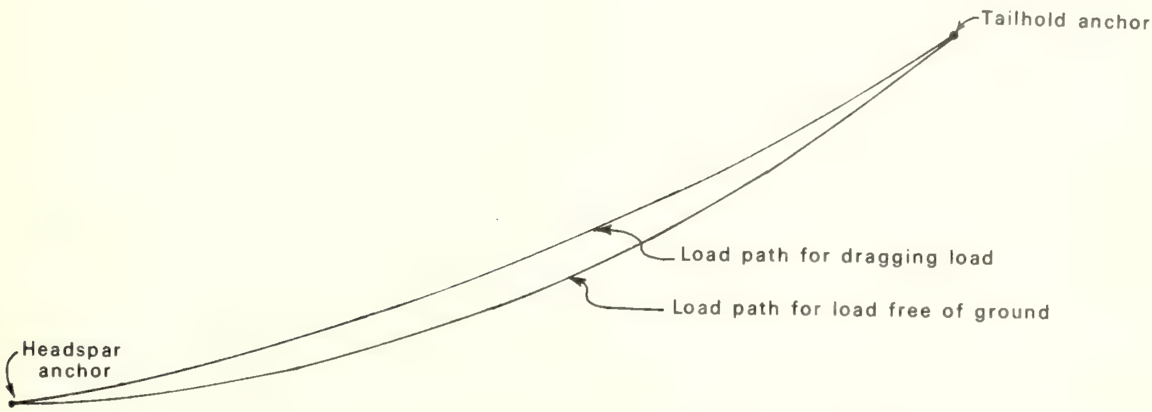


Figure 13.—Plotted results for running skyline (no profile shown).

Figure 14 shows the printed output which summarizes input information, line tensions, and forces in addition to the coordinates of points on the load path. There are four columns of line tension information for each load path point. Figure 12 shows the carriage configuration that was assumed to compute these tensions. Actually, the TAGLINE tension and the MAIN+SLACK tensions are independent of this specific configuration; however, the last two columns report special cases that may arise in the carriage shown. The MIN. MAIN tension would occur if the tagline block were not against the carriage and the slack-pulling line was tensioned to pick up a share of the MAIN+SLACK tension requirement. The amount it would share is in the last column, MAX. SLACK. The other likely operating mode is for the tagline block to be against the carriage, in which case the main line would carry the majority of the load up to a maximum of the MAIN+SLACK amount. Therefore the tensions in the printed output provide the extremes that could be encountered.

```
                    **RUNNING [illegible] PROGRAM**
SALE IDENTIFICATION- EXAMPLE [illegible]

DESCRIBE THE EQUIPMENT.


      HAULBACK WEIGHT PER FOOT  1.[illegible]     POUNDS/FOOT
      ALLOWABLE WORKING TENSION FOR HAULBACK  19600    POUNDS
      WEIGHT OF MAIN PLUS SLACK-PULLING LINE 1.44     POUNDS/FOOT
      WEIGHT OF CARRIAGE [illegible]     POUNDS

CORRIDOR NUMBER [illegible]
      HEADSPAR AND TAILHOLD HORIZ. DIST.= 1500     FEET
      HEADSPAR TO TAILHOLD VERTICAL DEVIATION=600  FEET
      ANTICIPATED SIZE OF TURN [illegible]   POUNDS     FREE OF GROUND
   LOAD PATH COORDINATES AND LINE TENSIONS
*DIST.:HEADSPAR TO LOAD*                     *LINE TENSIONS*
    HORZ        VERT.            HAULBACK     MAIN+SLACK   MIN.MAIN   MAX SLACK
     150        [illegible]      [illegible]  17036        13519      3519
     300        [illegible]      [illegible]  16699        13350      3350
     450        [illegible]      [illegible]  16380        13190      3190
     600        [illegible]      [illegible]  16081        13040      3040
     750        [illegible]      [illegible]  15804        12902      2902
     900        [illegible]      [illegible]  15553        12776      2776
    1050        [illegible]      [illegible]  15[illegible] 12664     2664
    1200        [illegible]      [illegible]  151[illegible] 12566    2566
    1350        [illegible]      [illegible]  149[illegible] 12484    2464
    1500        600          TAILHOLD LOCATION
      ANTICIPATED SIZE OF TURN [illegible]   POUNDS     DRAGGING
      DESIRED ANGLE OF [illegible] WITH RESPECT TO GROUND 20.00    DEGREES
      COEFFICIENT OF FRICTION [illegible]
   LOAD PATH COORDINATES AND LINE TENSIONS
*DIST.:HEADSPAR TO LOAD*                     *LINE TENSIONS*
    HORZ.       VERT.            HAULBACK     MAIN+SLACK   MIN.MAIN   MAX.SLACK
     150        [illegible]      [illegible]  190[illegible] 12104    6926
     300        [illegible]      [illegible]  18830        11993      6867
     450        [illegible]      [illegible]  18701        11892      6809
     600        [illegible]      [illegible]  18554        11800      6755
     750        [illegible]      [illegible]  18421        11718      6703
     900        [illegible]      [illegible]  18300        11646      6653
    1050        [illegible]      [illegible]  18194        11585      6609
    1200        [illegible]      [illegible]  18102        11536      6566
    1350        [illegible]      [illegible]  18025        11499      6527
    1500        600          TAILHOLD LOCATION
```

Figure 14.—Printed output from the running skyline program.

LISTING OF THE RUNNING SKYLINE PROGRAM

```
10 REM PROGRAM TO AID IN THE LAYO[illegible] RUNNING S[illegible]LINE.
20 DIM T$[30]
30 PRINT TAB10"NOTE:GRAPH LIMITS [illegible] BE ESTABLISHED ON THE PLOTTER
40 DISP "HORIZONTAL GRAPH LIMITS[illegible]
50 INPUT G1
60 DISP "VERTICAL GRAPH LIMITS(FT)"
70 INPUT G2
80 SCALE 0,G1,0,G2
90 PLOT 0,0,1
100 PRINT TAB20"***RUNNING S[illegible]***
110 DISP "SALE IDENTIFICATION";
120 INPUT T$
130 PRINT "SALE IDENTIFICATION ";T$
140 PRINT TAB10"DESCRIBE THE [illegible]
150 DISP "HAULBACK WEIGHT (LB/FOOT)";
160 INPUT W1
170 W2=W1
180 PRINT TAB5"HAULBACK WEIGHT PER [illegible] POUNDS/FOOT"
190 DISP "HAULBACK WORKING TENSION[illegible]";
200 INPUT T
210 PRINT TAB5"ALLOWABLE WORKING [illegible] FOR HAULBACK ";T;"POUNDS
220 DISP "MAIN+SLACKLINE WEIGHT[illegible]";
230 INPUT W3
240 PRINT TAB5"WEIGHT OF MAIN [illegible] LINE";W3;"POUNDS/[illegible]"
250 DISP "CARRIAGE WEIGHT(LB)";
260 INPUT W6
270 PRINT TAB5"WEIGHT OF CARRIAGE";W6;"POUNDS";TAB[illegible]
280 DISP "CORRIDOR NUMBER";
290 INPUT T$
300 PRINT "CORRIDOR NUMBER ";T$
310 DISP "HORZ.DIST.:HEADSPAR T[illegible]";
320 INPUT L
330 PRINT TAB5"HEADSPAR AND [illegible] SPAN";L;"FEET"
340 DISP "ELEV.DIFF.:HEADSPAR TO [illegible]";
350 INPUT H
360 PRINT TAB5"HEADSPAR TO [illegible] ELEVATION";H;"FEET"
370 DISP "HORZ.DIST.:ORIGIN TO HE[illegible]";
380 INPUT X0
390 DISP "ELEV.DIFF.:ORIGIN TO HE[illegible]";
400 INPUT Y0
410 OFFSET X0,Y0
420 PLOT 0,0,-2
430 DEG
440 DISP "ANTICIPATED LOAD SIZE[illegible]";
450 INPUT W
460 DISP "LOG DRAGGING(RESPOND YE[illegible]";
470 INPUT T$
480 IF T$="YES" THEN 5[illegible]0
490 I1=0
```

```
500 PRINT TAB[illegible] FREE OF GROUND
510 GOTO 600
520 PRINT TAB5"ANTICIPATED [illegible] DRAGGING"
530 I1=1
540 DISP "DRAG ANGLE [illegible]
550 INPUT B1
560 PRINT TAB5"DESIRED ANGLE OF [illegible] WITH RESPECT TO GROUND"E1,"DEGREES"
570 DISP "COEFFICIENT OF FRICTION"
580 INPUT M1
590 PRINT TAB5 [illegible] M1
600 PRINT " LOAD [illegible] LINE TENSIONS"
610 PRINT "[illegible] *LINE TENSIONS*
620 PRINT " [illegible] MAIN+SLACK MIN.MAIN MAX.S
630 E1=2
640 REM LOOP FOR CARRIAGE POSITION
650 N=I=0
660 N=N+1
670 D1=L*N/10
680 REM LOOP FOR DEFLECTION
690 REM INITIAL GUESS
700 H2=T*L/SQR(H[illegible]+L[illegible])
710 REM CONVENIENT GUESS [illegible]
720 Y1=H/L*D1
730 R1=W1*SQR(Y1[illegible]+D1[illegible]2
740 R3=W3*SQR(Y1[illegible]2+D1[illegible]2
750 R2=W2*SQR((Y1-H)[illegible]2+(L-D1)[illegible]
760 R4=R1+R3+2*R2
770 GOTO 910
780 Y1=(W4+W[illegible]*H2*D1)
790 F1=SQR(H2[illegible]2+[illegible]-D1)+R2[illegible]2/4)
800 F3=ABS(T-W1*Y1-F1)
810 IF F3<0.01 THEN 860
820 F2=(T-W1*Y1)/F1*H2
830 FIXED 2
840 H2=F2
850 GOTO 730
860 FIXED 2
870 GOSUB 1050
880 WRITE (15,890)D1[illegible]
890 FORMAT F8.0,F10.0,[illegible],F10.[illegible]
900 GOTO 1130
910 REM AN ESTIMATE OF GROUND ANGLE [illegible] DEFLECTION GEOMETRY IS MADE.
920 A1=0.5*(Y1/D1-(Y1-H)/(L-D1))[illegible]3.14159
930 C1=COS(A1)
940 S1=SIN(A1)
950 IF I1=1 THEN 1000
960 REM THE LOAD SUSPENDED OPTION.
970 W4=W
980 W5=0
990 GOTO 1030
```

```
1000 N2=TAN(B1)
1010 W4=W*(1-(C1-S1*N2)/E1/(1+M1*N2)-[illegible]M1*S1))
1020 W5=W*(C1-S1*N2)/E1/(1+M1*N2)-[illegible]M1*C1)
1030 T5=SQR(W4↑2+W5↑2)
1040 GOTO 780
1050 REM COMPUTING COMBINED MAIN AND [illegible]-PULLING LINE TENSIONS.
1060 A1=(R1*Y1/D1)↑2-4*(1+(Y1/D1)↑2)*(R1*R1/4-T1↑2)
1070 H1=(R1*Y1/D1+SQR(A1))/2/(1+(Y1/D1)↑2)
1080 H3=2*H2+W5-H1
1090 T3=SQR(H3↑2+(H3*Y1/D1)↑2-H3*[illegible]+R3*R3/4)
1100 T6=(T3+T5)/2
1110 T7=(T3-T5)/2
1120 RETURN
1130 I=I+1
1140 M[I]=D1
1150 N[I]=Y1
1160 IF N<9 THEN 660
1170 WRITE (15,890)L,h,'   TAILHOLD LOCATION'
1180 DISP "DO YOU WANT A PLOT";
1190 INPUT T$
1200 IF T$="NO" THEN 1270
1210 PLOT 0,0,-2
1220 FOR K=1 TO 9
1230 PLOT M[K],-N[K],-2
1240 NEXT K
1250 PLOT L,-h,2
1260 PEN
1270 DISP "TRY ANOTHER PAYLOAD";
1280 INPUT T$
1290 IF T$="YES" THEN 440
1300 PRINT TAB100,TAB25"**************NEW PATH, RELOCATE PEN"
1310 PRINT TAB25"****************************************",TAB100
1320 GOTO 280
1330 END
```

MULTISPAN SKYLINE LOAD PATH PROGRAM

This program examines the tensions, loads, and deflections of a multispan skyline such as the one shown in figure 15. The system consists of a skyline anchored at a headspar and tailhold with additional intermediate supports at selected points between the anchors. In two sections of the program ("Equipment Description" and "Geometry Description" in table 4), the skyline size and the geometry of the anchoring and intermediate support locations are entered as input. With this information, the program can compute either the load that can be supported at any point (trial load section) or the tensions and deflections resulting from a given line length and load (load path section). In both these sections, the loading at intermediate supports is determined. This information can be used to determine the feasibility of the multispan skyline configuration which can be extremely sensitive to proper placement of anchors and supports, length of lines, and size of loads.

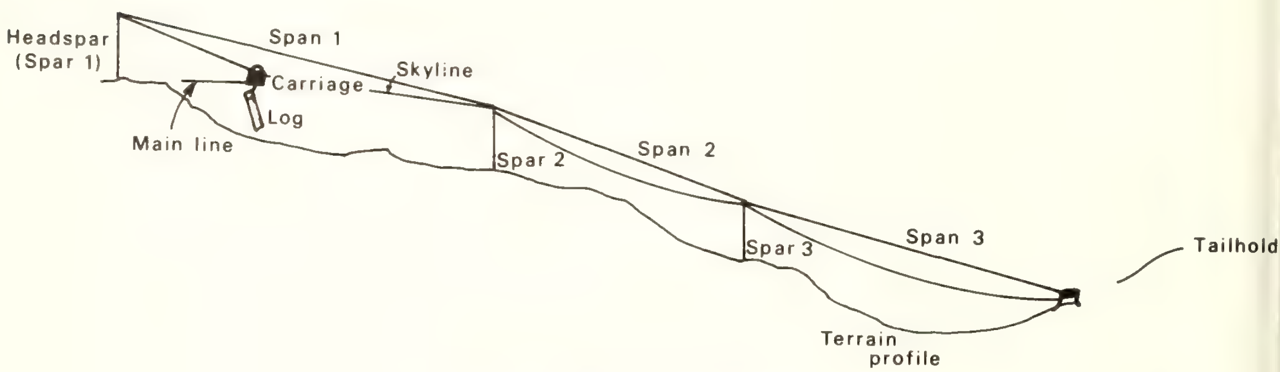


Figure 15.—Multispan skyline.

User Instructions

The following example demonstrates use of this program. The first step is to load file 1 (i.e., LOADKEY 1, EXECUTE) and then continue through the following procedure:

1. Press STOP and END to prepare for loading the program.
2. Press function key f_9 (or LOAD 5, EXECUTE).
3. Adjust graph limits on plotter.
4. Continue with the procedure outlined in table 4 by responding to the visual prompters with the numerical or alphanumeric entries indicated in the middle column. The DESCRIPTIONS should be read for an understanding of the process.

Table 4.--Input explanation for multispan skyline example

VISUAL PROMPTER ON DISPLAY	KEYBOARD RESPONSE	DESCRIPTION
HORIZONTAL GRAPH LIMITS (FEET)?	2000	Enters scale value for X-axis on plotter.
VERTICAL GRAPH LIMITS (FEET)?	1400	Enters scale value for Y-axis on plotter.
Equipment description		
SKYLINE SIZE (LB/FOOT)?	2.89	Enters weight per foot of skyline.
ALLOWABLE WORKING TENSION (LB)?	53300	Enters allowable working tension of skyline.
Geometry description		
CORRIDOR NUMBER?	4	Enters number to identify skyline corridor.
HORZ. DIST.: HEADSPAR TO TAILHOLD?	1500	Enters overall skyline span.
ELEV. DIFF.: HEADSPAR TO TAILHOLD?	450	Enters vertical anchor point separation from top of headspar down to top of tailhold.
HORZ. DIST.: HEADSPAR TO SPAR 2?	600	Enters horizontal distance to first intermediate spar.
ELEV. DIFF.: HEADSPAR TO SPAR 2?	150	Enters vertical distance from top of headspar down to jack on first intermediate spar.
HORZ. DIST.: HEADSPAR TO SPAR 3?	1000	Enters horizontal distance to second intermediate spar.
ELEV. DIFF.: HEADSPAR TO SPAR 3?	300	Enters vertical distance from top of headspar down to jack on second intermediate spar.
HORZ. DIST.: HEADSPAR TO SPAR 4?	0	Causes program control to branch to trial load section of program.
Trial load section		
HORZ. DIST.: HEADSPAR TO LOAD?	300	Enters horizontal distance to first trial load location.
ELEV. DIFF.: HEADSPAR TO LOAD?	150	Enters vertical distance from top of headspar down to carriage location for first trial.
HORZ. DIST.: HEADSPAR TO LOAD?	800	Enters horizontal distance to second trial load location.
ELEV. DIFF.: HEADSPAR TO LOAD?	300	Enters vertical distance from top of headspar down to carriage location for second trial.
HORZ. DIST.: HEADSPAR TO LOAD?	1300	Enters horizontal distance to third trial load location.
ELEV. DIFF.: HEADSPAR TO LOAD?	450	Enters vertical distance from top of headspar down to carriage location of third trial.
HORZ. DIST.: HEADSPAR TO LOAD?	0	Causes program control to branch to the load path section of program.
Load path section		
HORZ. DIST.: ORIGIN TO HEADSPAR?	100	Enters horizontal distance from origin to the top of the headspar. The origin is lower left graph limits set by the operator.
ELEV. DIFF.: ORIGIN TO HEADSPAR?	1000	Enters vertical distance from origin to top of the headspar.
NUMBER OF POINTS TO BE EXAMINED?	3	Establishes the number of data points that will be examined in each intermediate span (in addition to a point in the immediate vicinity of each support).

Table 4.--Input explanation for multispan skyline example (Continued)

VISUAL PROMPTER ON DISPLAY	KEYBOARD RESPONSE	DESCRIPTION
NEW LOAD PATH?	YES	Transfers program control to section for computing a second load path over this same arrangement of anchors and spars.
LINE LENGTH?	1570	Enters unstretched line length for second load path.
LOAD?	10000	Enters load to be used for new load path.
NUMBER OF POINTS TO BE EXAMINED?	3	Same as above.
NEW LOAD PATH?	NO	Branches out of load path section.
NEW ANCHORING OR SPAR GEOMETRY?	NO	Branches to next query.
MARK BOTTOM OF LOAD?	YES	Branches to section for load labeling.
CLEARANCE REQUIRED: CABLE TO GRD?	60	Enters length required to provide clearance for the carriage, chokers, and logs between the skyline cable and the ground. After labeling plot with arrows to represent this length, terminates program.

Output

This program prepares both plotted and printed output. The plotted results (fig. 16) present the load path of the point of contact between the carriage and skyline. The number of points involved in this plot was selected during program execution.

Figure 17 shows a sample of printed output which summarizes the input information and the tensions, line lengths, and forces in addition to the coordinates of points on the load path. The forces and geometry at each load point and reactions at the intermediate spars are printed. Figure 18 shows how this information should be interpreted.

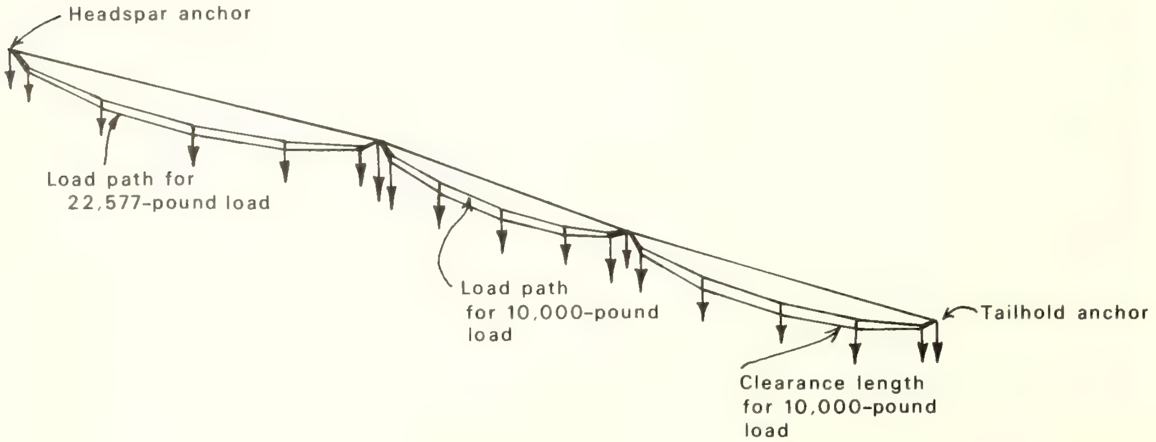
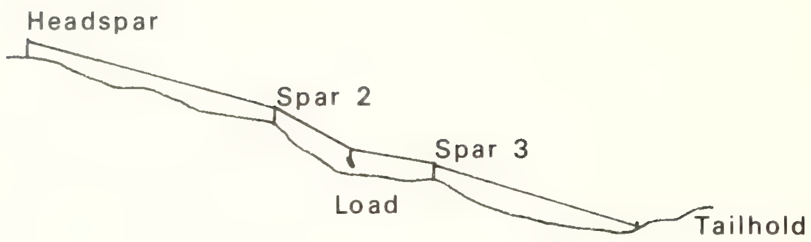


Figure 16.—Multispan skyline plotted results (no profile shown).

```
                     **** MULTISPAN PROGRAM. ****
SALE IDENTIFICATION- EXAMPLE #4
          EQUIPMENT DESCRIPTION.
                SKYLINE SIZE 2.89     POUNDS PER FOOT
                ALLOWABLE WORKING TENSION= 53300   POUNDS


 CORRIDOR NUMBER- 4
HORIZONTAL DISTANCE(D) FROM HEADSPAR TO TAILHOLD= 1500    FEET
ELEVATION DIFFERENCE(H) FROM HEADSPAR TO TAILHOLD= 450  FEET
      INTERMEDIATE SPAR 2    D 600  H 150
      INTERMEDIATE SPAR 3    D 1000    H 300
     TRIAL LOAD LOCATED AT  300 IN SPAN 1 WITH ELEVATION FROM HEADSPAR OF  15
          STRETCHED LENGTH 1594.630   UNSTRETCHED LENGTH 1576.383
               D         H       FORCE ANGLE     FORCE
              300       150          76.72         23443   LOAD= 22821
              600       150          79.64        -19860
             1000       300          71.29          2229
     TRIAL LOAD LOCATED AT  800 IN SPAN 2 WITH ELEVATION FROM HEADSPAR OF  30
          STRETCHED LENGTH 1550.487   UNSTRETCHED LENGTH 1532.209
               D         H       FORCE ANGLE     FORCE
              600       150          64.86        -22061
              800       300          71.57         32613   LOAD= 30939
             1000       300          81.41        -16222
     TRIAL LOAD LOCATED AT 1300 IN SPAN 3 WITH ELEVATION FROM HEADSPAR OF  45
          STRETCHED LENGTH 1581.031   UNSTRETCHED LENGTH 1572.853
               D         H       FORCE ANGLE     FORCE
              600       150          77.80        -7455
             1000       300          66.52        -6506
             1300       450          76.96         23190   LOAD= 22577
 LOAD PATH BEING COMPUTED FOR LINE LENGTH OF 1572.853 AND LOAD OF  22577
     PREPARING FOR LOAD PATH BY SAMPLING 3    POINTS PER SPAN
              SPAR 1     D 0    H 0
              SPAR 2     D 600  H 150
              SPAR 3     D 1000    H 300
              SPAR 4     D 1500    H 450
     LOAD AT     30,DEFLECTED TO   38.6    ,HEADSPAR TENSION OF  39299
         SPAR LOADS     D          H     FORCE ANGLE       FORCE
                        30         39     57.83            26673 LOAD= 22579
                       600        150     74.37            -7828
                      1000        300     71.26             1286
     LOAD AT    150,DEFLECTED TO   97.7    ,HEADSPAR TENSION OF  54647
         SPAR LOADS     D          H     FORCE ANGLE       FORCE
                       150         93     69.92            24039 LOAD= 22578
                       600        150     76.45           -14367
                      1000        300     71.30             2319
     LOAD AT    300,DEFLECTED TO  143.      ,HEADSPAR TENSION OF  57651
         SPAR LOADS     D          H     FORCE ANGLE       FORCE
                       300        143     71.59            23209 LOAD= 22577
                       600        150     74.01           -20166
                      1000        300     71.30             2524
```

Figure 17.—Portion of printed output from multispan skyline program.



LOAD AT 800,DEFLECTED TO 266.4 ,HEADSPAR TENSION OF 32003

SPAR LOADS	D	H	FORCE ANGLE	FORCE	
	600	150	68.41	-10019	
	800	266	70.13	10632	LOAD= 10000
	1000	300	76.48	-4898	

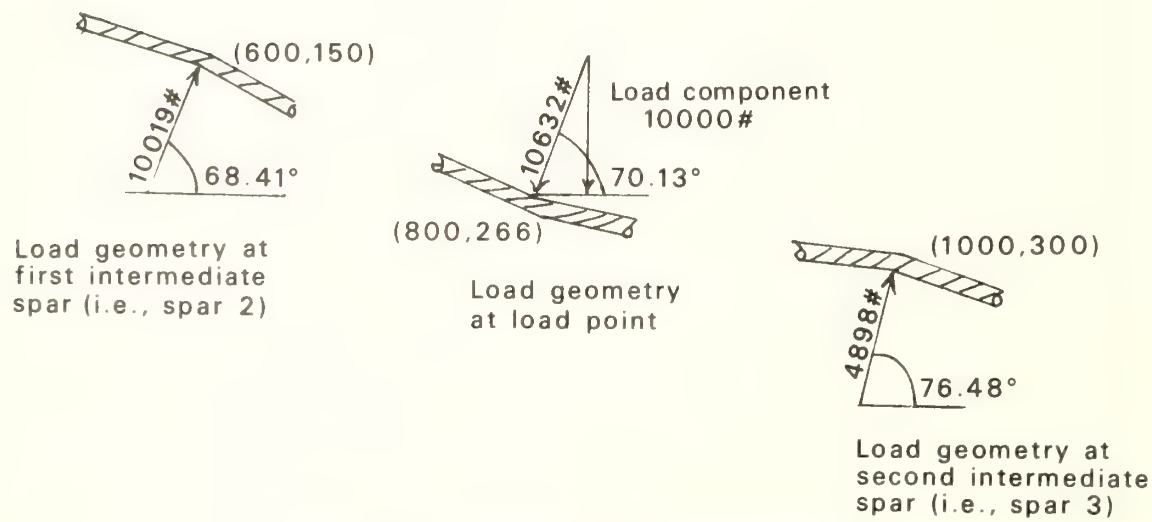


Figure 18.—Interpretation of load path printout.

LISTING OF THE MULTISPAN PROGRAM

```
10 REM PROGRAM [illegible]
20 DIM [illegible]
30 PRINT TAB[illegible]
40 DISP "HORIZONTAL [illegible]
50 INPUT C1
60 DISP "VERTICAL [illegible]
70 INPUT C2
80 SCALE [illegible]
90 PLOT 0,0,1
100 PRINT TAB[illegible]
110 DISP "SALE IDENTIFICATION";
120 INPUT I$
130 PRINT "SALE IDENTIFICATION- [illegible]
140 REM*****CONTROLS*****
150 REM        12 IDENTIFIC[illegible]
160 REM      13-1 LOAD IDENTIFICATION [illegible]
170 REM ************LENGTH [illegible] PORTION OF PROGRAM [illegible]
180 REM***INPUT***
190 PRINT TAB5"EQUIPMENT DESCRIPTION"
200 DISP "SKYLINE SIZE(LB/FOOT)";
210 INPUT W1
220 PRINT TAB15"SKYLINE [illegible] PER FOOT"
230 DISP "ALLOWABLE WORKING TENSION[illegible]";
240 INPUT T
250 PRINT TAB15"ALLOWABLE WORKING TENSION= "T"POUNDS"
260 PRINT TAB100
270 T1=T
280 DISP "CORRIDOR NUMBER";
290 INPUT I$
300 PRINT " CORRIDOR NUMBER-  "I$
310 DISP "HORZ.DIST.:HEADSPAR TO TAILHOLD";
320 INPUT L1
330 PRINT "HORIZONTAL DISTANCE(FT) FROM HEADSPAR TO TAILHOLD="L1"FEET"
340 DISP "ELEV.DIFF.:HEADSPAR TO TAILHOLD";
350 INPUT H1
360 PRINT "ELEVATION DIFFERENCE[illegible] HEADSPAR TO TAILHOLD="H1[illegible]
370 E1=3500000
380 E0=S0=W=1000000
390 N=1
400 REM ENTER COORDINATES OF INTERMEDIATE SPANS
410 N=N+1
420 DISP "HORZ.DIST.:HEADSPAR TO [illegible]";
430 INPUT D[N]
440 IF D[N]=0 THEN 490
450 DISP "ELEV.DIFF.:HEADSPAR TO [illegible]";
460 INPUT H[N]
470 PRINT "       INTERMEDIATE SPAN [illegible]"D[N]"[illegible]"H[N]
480 GOTO 400
490 REM ESTABLISH LEFT AND RIGHT [illegible] POINTS
500 D[1]=0
510 D[N]=L1
520 H[1]=0
```

```
530 H[N]=H1
540 I3=0
550 REM***TRIALS OF LOAD POINTS.
560 DISP "HORZ.DIST.:HEADSPAR TO LOAD";
570 INPUT X1
580 IF X1=0 THEN 930
590 DISP "ELEV.DIFF.:HEADSPAR TO LOAD";
600 INPUT Y1
610 GOSUB 1690
620 WRITE (15,630)X1,I1," WITH ELEVATION FROM HEADSPAR OF";Y1
630 FORMAT 4X,"TRIAL LOAD LOCATED AT",F5.0," IN SPAN",F2.0,F5.0
640 REM***GET SPAR LOADS
650 FOR I=2 TO N
660 GOSUB 2060
670 NEXT I
680 REM***GET TOTAL STRETCHED AND UNSTRETCHED LINE LENGTH.
690 GOSUB 2190
700 WRITE (15,710)S4,S2
710 FORMAT 9X,"STRETCHED LENGTH",F9.3,3X,"UNSTRETCHED LENGTH",F9.3
720 PRINT TAB10;"     D          H       FORCE ANGLE     FORCE"
730 FOR I=2 TO N
740 C1=C[I]*180/PI
750 IF I#I2 THEN 800
760 W0=F[I]*SIN(C[I])
770 WRITE (15,780)D[I],H[I],C1,F[I],W0
780 FORMAT 8X,2F8.0,5X,F7.2,F12.0,"    LOAD=",F6.0
790 GOTO 820
800 WRITE (15,810)D[I],H[I],C1,F[I]
810 FORMAT 8X,2F8.0,5X,F7.2,F12.0
820 NEXT I
830 REM***GET MINIMUM LOAD,LINE LENGTH AND DEFLECTION.
840 IF W0>W THEN 870
850 S0=S2
860 W=W0
870 Y2=H[I2-1]+(X1-D[I2-1])*(H[I2]-H[I2-1])/(D[I2]-D[I2-1])
880 E2=(Y1-Y2)/(D[I2+1]-D[I2-1])
890 IF E2>E0 THEN 910
900 E0=E2
910 GOSUB 2450
920 GOTO 550
930 REM*************LOAD PATH PORTION OF PROGRAM**************
940 WRITE (15,950)S0," AND LOAD OF",W
950 FORMAT "LOAD PATH BEING COMPUTED FOR LINE LENGTH OF",F9.3,F7.0
960 DISP "HORZ.DIST.:ORIGIN TO HEADSPAR";
970 INPUT X0
980 DISP "ELEV.DIST.:ORIGIN TO HEADSPAR";
990 INPUT Y0
1000 OFFSET X0,Y0
1010 PLOT 0,0,1
1020 DISP "NUMBER OF POINTS TO BE COMBINED";
1030 INPUT N2
```

```
1040 PRINT "     PREPARING FOR LOAD PATH BY EXAMINING"N2;"POINTS PER SPAN"
1050 N0=N-1
1060 FOR I=1 TO N0
1070 PRINT "                 SPAR"I;"D"D[I];"H"H[I]
1080 NEXT I
1090 REM***ESTABLISH SET OF POINTS FOR LOAD PATH COMPUTATIONS.
1100 X[1]=D[1]
1110 Y[1]=H[1]
1120 FOR J=2 TO N
1130 J1=(J-1)*(N2+3)+1
1140 X[J1]=D[J]
1150 Y[J1]=H[J]
1160 J2=J-1
1170 D8=D[J]-D[J-1]
1180 H8=H[J]-H[J-1]
1190 PLOT D[J2],-H[J2],2
1200 FOR K=1 TO (N2+2)
1210 I=(J-2)*(N2+3)+K+1
1220 IF K#1 THEN 1250
1230 X[I]=D[J-1]+0.05*D8
1240 GOTO 1290
1250 IF K#(N2+2) THEN 1280
1260 X[I]=D[J]-0.05*D8
1270 GOTO 1290
1280 X[I]=(D[J]-D[J-1])*(K-1)/(N2+1)+D[J-1]
1290 Y[I]=(X[I]-D[J-1])*H8/D8+H[J-1]+F[J]*D8
1300 NEXT K
1310 NEXT J
1320 M=(N-2)*(N2+3)+N2+4
1330 X[M]=D[N]
1340 Y[M]=H[N]
1350 PRINT TAB13"SPAR"N;"D"X[M];"H"Y[M]
1360 PLOT X[M],-Y[M],2
1370 PLOT 0,0,1
1380 REM***DETERMINE DEFLECTION AND LOAD AT EACH POSITION.
1390 FOR J=2 TO N
1400 J1=(J-1)*(N2+3)+1
1410 J2=J-1
1420 FOR K=1 TO (N2+2)
1430 J3=(J-2)*(N2+3)+K+1
1440 X1=X[J3]
1450 Y1=Y[J3]
1460 GOSUB 1830
1470 Y[J3]=H[I2]
1480 WRITE (15,1490)X[J3],Y[J3]," NEAR SPAR TENSION OF"T1
1490 FORMAT 4X,"LOAD AT",F6.0,",DEFLECTED TO",F7.1,3X,F7.0
1500 PRINT TAB8"SPAR LOADS     D          H     FORCE ANGLE      FORCE"
1510 REM***DETERMINE SPAR LOADS AND ANGLES. ***
1520 FOR I=2 TO N
1530 GOSUB 2060
1540 C1=C[I]*180/PI
1550 C2=F[I]*SIN(C[I])
1560 IF I#I2 THEN 1600
1570 WRITE (15,1580)D[I],H[I],C1,F[I],C2
```

```
1580 FORMAT [illegible]
1590 GOTO 1620
1600 WRITE [illegible]
1610 FORMAT [illegible]
1620 NEXT I
1630 IF [illegible] THEN 1650
1640 GOSUB [illegible]
1650 NEXT K
1660 NEXT J
1670 GOTO [illegible]
1680 REM[illegible]******************
1690 REM[illegible]SUB[illegible] [illegible] REPRESENT LOAD AS SPAR.
1700 FOR I2=2 TO N
1710 IF [illegible] THEN [illegible]
1720 NEXT I2
1730 FOR I1=[illegible] TO [illegible] STEP [illegible]
1740 D[I1+1]=D[I1]
1750 H[I1+1]=H[I1]
1760 NEXT I1
1770 N1=N+1
1780 D[I2]=X1
1790 H[I2]=Y1
1800 I1=I2-1
1810 I3=1
1820 RETURN
1830 REM[illegible] [illegible] FROM LOAD AND LINE LENGTH.
1840 GOSUB [illegible]
1850 REM[illegible] [illegible]
1860 D8=D[I2+1]-D[I2-1]
1870 H[I2]=Y1-D8*[illegible]
1880 GOSUB [illegible]
1890 GOSUB [illegible]
1900 Y1=H[I2]
1910 S5=S0-S2
1920 H[I2]=Y1+D8[illegible]
1930 N9=1
1940 GOSUB [illegible]
1950 GOSUB 2190
1960 S3=S0-S2
1970 IF ABS(S[illegible])<0.2 THEN [illegible]
1980 Y2=(H[I2]-Y1)*S[illegible]
1990 S5=S3
2000 Y1=H[I2]
2010 H[I2]=H[I2]-Y2
2020 DISP "POINT"[illegible]
2030 N9=N9+1
2040 GOTO 1940
2050 RETURN
2060 REM[illegible]SUB[illegible]EVALUATE [illegible] AND DIRECTION OF SPAR LOADS.
2070 G1=H[I+1]-H[I]
2080 G2=D[I+1]-D[I]
2090 G3=H[I]-H[I-1]
2100 G4=D[I]-D[I-1]
```

```
2110 T[I]=T1-W1*H[I]
2120 A1=ATN(-G1/G2)
2130 A2=PI-ATN(G3/G4)
2140 B1=W1/2/T[I]*G2
2150 B2=W1/2/T[I]*G4
2160 C[I]=0.5*(A1+A2-[illegible]
2170 F[I]=2*T[I]*COS((A2-A1)[illegible]
2180 RETURN
2190 REM***SUB4***COMPUTE [illegible]
2200 S2=S4=0
2210 FOR I1=2 TO N1
2220 G3=H[I1]-H[I1-1]
2230 G4=D[I1]-D[I1-1]
2240 T[I1]=T1-W1*H[I1]
2250 A2=PI-ATN(G3/G4)
2260 B2=W1/2/T[I1]*G4
2270 M1=ABS(T[I1]*COS(A2-[illegible]
2280 S1=SQR(G3↑2+G4↑2+(1+[illegible]
2290 D0=G4/2/M1
2300 D3=1+1/6*D0↑2-1/[illegible]
2310 S[I1-1]=S1-M1/(E1+W1[illegible]
2320 S2=S2+S[I1-1]
2330 S4=S4+S1
2340 NEXT I1
2350 RETURN
2360 REM***SUB5***COMPUTE TENSION [illegible] GEOMETRY [illegible] LOAD.
2370 G1=H[I2+1]-H[I2]
2380 G2=D[I2+1]-D[I2]
2390 G3=H[I2]-H[I2-1]
2400 G4=D[I2]-D[I2-1]
2410 A1=ATN(-G1/G2)
2420 A2=PI-ATN(G3/G4)
2430 T1=(W+W1/2*(G2*COS(A1[illegible]SIN(A2[illegible]
2440 RETURN
2450 REM***SUB6***RE-ESTABLISH [illegible]DINATES.
2460 FOR I=I2 TO N
2470 D[I]=D[I+1]
2480 H[I]=H[I+1]
2490 NEXT I
2500 I3=0
2510 RETURN
2520 REM***PLOT OF LOAD PATH
2530 FOR J3=1 TO M
2540 PLOT X[J3],-Y[J3]
2550 NEXT J3
2560 PEN
2570 REM***RECOVERY PROCESS FOR [illegible]
2580 IF I3=0 THEN 2600
2590 GOSUB 2450
2600 DISP "NEW LOAD PATH";
2610 INPUT T$
2620 IF T$#"YES" THEN 2700
2630 DISP "LINE LENGTH";
2640 INPUT S0
```

```
2650 DISP "LOAD";
2660 INPUT W
2670 WRITE (15,2680)S0," AND LOAD OF";W
2680 FORMAT "LOAD PATH BEING COMPUTED FOR LINE LENGTH OF";F9.3;F7.0
2690 GOTO 1010
2700 DISP "NEW ANCHORING OR SPAR GEOMETRY";
2710 INPUT T$
2720 IF T$="YES" THEN 260
2730 DISP "MARK BOTTOM OF LOAD";
2740 INPUT T$
2750 IF T$#"YES" THEN 2840
2760 REM MARK BOTTOM OF LOAD.
2770 DISP "REQUIRED CLEARANCE:CABLE TO GRD";
2780 INPUT C1
2790 FOR J3=1 TO M
2800 PLOT X[J3],-Y[J3],1
2810 LABEL (2820,C1/14,6,0.1[illegible]
2820 FORMAT B
2830 NEXT J3
2840 PRINT TAB100
2850 GOTO 180
2860 END
```

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

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P.O. Box 3141
Portland, Oregon 97208

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OPTIMUM INSULATION THICKNESS IN WOOD-FRAMED HOMES

A. E. OVIATT

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
PORTLAND, OREGON

Abstract

New design methods must be developed to reduce energy waste in buildings. This study examines an economic approach to the design of thermal insulation in the home and demonstrates graphically that an optimum point of insulation thickness occurs where total costs of insulation and energy over the useful life of a building are a minimum. The optimum thickness thus determined exceeds that recommended by older design criteria and significantly reduces energy requirements for heating and cooling. An engineering heat loss analysis is applied to typical wood-framed wall and roof constructions, and total costs of insulation and energy are graphically shown for various thicknesses of insulation in several climates of the United States. Simple expressions are derived which may be used by designers and contractors to estimate optimum insulation thicknesses for any climate, using a series of curves. This method of design is new and results in greater total cost economy and better energy conservation than previous methods. Other ways of reducing heat loss in the home are also discussed.

Keywords : Wood properties (thermal), construction (wood).

Contents

Introduction

The energy shortage in the United States is now clearly visible, and measures to conserve our existing supplies of energy fuels and to develop new sources are urgently needed. The problem has many facets and implications, but there is an immediate need for effective conservation methods. We must operate within our present means to allow time for the development of other potential energy sources, so that the least disruption in our economy and our way of life will occur.

A very significant reduction in energy use can be made by curtailing the enormous waste of energy we have tolerated in our residential heating systems by inadequate design of thermal insulation. Of some 71 million housing units now existing in the United States, a large majority has insufficient insulation or other thermal treatment.

Thermal insulation, as such, was not widely used in residential buildings until the 1930's. Hence, a large number of older dwellings are without insulation, other than that afforded by the construction itself. Some of these older houses have since been improved, but many remain with grossly inefficient and costly thermal systems. Newer houses are frequently nominally insulated, but a majority do not have adequate thermal protection, either because good standards were not generally known or because so-called "first-cost" was the controlling factor to the builder.

Many of our older buildings would be difficult or costly to significantly improve thermally. Such is the case with many multifamily apartments and the growing number of mobile homes, many of the latter being notoriously difficult to heat. However, simple alterations to the 48 million existing one- and two-family dwellings can be easily and economically made. The installation or improvement of ceiling insulation and the use of storm windows and doors in northern locations can usually save 20 percent or more in heating and cooling costs.

An energy saving of more than 1,400 trillion Btu's per year has been estimated (*7*), if these improvements to existing homes were made. This translates to a saving of some $3 billion per year, enough to pay for the improvements in a very short time.

A continuing opportunity to conserve our available energy is presented in current and future residential construction, which normally adds some 2 million units each year to our heating and cooling load. If insulation in these units were increased to an optimum level, considerable reduction in energy use would result, with an attendant reduction in total cost. The saving, of course, would be a progressive one as new housing is built, but additional savings of some 6,000 trillion Btu's are possible over a 10-year period due to improved insulation of all new construction. Such a saving would offset present trends toward larger living units and greater use of air conditioning which, if they continue, will increase energy demands per living unit.

Where future construction is concerned, important steps have already been taken to increase insulation requirements, as in Federal Housing Administration Minimum Property Standards, 1974, for FHA insured construction and the Oregon State Building Code, 1974. However, maximum energy savings can only be assured when an individual investing in a home realizes the total economy of adequate insulation, and this study seeks to inform owners as well as designers and builders.

An important side effect of energy conservation is a proportional reduction in air pollution, since pollution occurs in direct proportion to the amount of fuels consumed. It is, therefore, more desirable in reduced air pollution, as well as economy, to curtail the amount of energy used per living unit than to develop new sources or quantities of usable energy.

Design of Insulation

Insulation design involves a choice of material and form, as well as a determination of thickness needed. It is not the purpose of this study to discuss materials and forms in great detail. It is important that the material be fire-resistant, and one that does not produce noxious gases on exposure to heat. It should be resilient enough to prevent compaction and should not readily absorb or be damaged by water vapor. In typical wood-frame houses, batts or blankets are well suited to fitting between studs or rafters, and loose, fill-type materials may be readily blown over ceiling joists. This type of installation, using glass or rock wool, is in general use and is widely recognized for its economy in wood-frame construction. Therefore, insulation and cost values used in this study will be limited to this material. Other kinds of insulation, such as insulating board sheathing, foamed plastic board types, and vermiculite fill have important applications but are not so widely used.

Insulation Thickness

Given the material and form of insulation most widely used in the typical wood-frame house, how shall we determine how much to use? Most previous methods of design emphasize comfort criteria, i.e., the essential design

requirement being that occupants of a building are entitled to a thermally comfortable environment. It is presumed to follow that this would also be a healthful environment. Among widely used rules of thumb to achieve average comfort conditions are:

1. "All Weather Comfort Standard," as developed by manufacturers, equipment suppliers, and power companies. This standard provides a range of choice of insulation thickness based on three arbitrary weather zones (*6*), using the degree-day[1/] heating requirement to define these zones.

2. Comfort criteria based on the average difference between desired room air temperature and that of enclosing surfaces. An average balance of heat gained by convection and heat lost by radiation is thus obtained, and criteria are applied from experience as to what this difference should be (*4*).

These standards address the fundamental requirements of comfort and health of the occupants but provide little guidance to the designer or builder on the economic use of insulation or on energy conservation. Illustrations are sometimes provided to show the savings in heating cost which can be made by adding another inch of insulation, but no attempt is made to arrive at an economic optimum.

A 1971 publication of the National Association of Home Builders (*5*) recognizes the growing use of air conditioning in American homes and provides an excellent guide for the designer or builder in analyzing heat losses and energy costs. It provides heating and cooling worksheets whereby the builder may enter trial combinations of insulation and openings, determining total heat transfer and equipment sizes. Simple cost calculations are provided, establishing heating and cooling costs for a given heat transfer in any part of the United States. It does not, however, identify the optimum economic thickness of insulation which results in the least total cost (insulation plus operating cost) to the owner. Rather, it leaves it to the builder to choose constructions in a manner to result in least first-cost, and to use what he feels is a reasonable level of insulation thickness acceptable to a buyer.

The first-cost approach has never been conducive to the best interests of the typical home buyer, since the few hundred dollars saved by eliminating or minimizing insulation can cost the owner a few thousand dollars over the life of the building in increased energy costs. We can no longer afford this kind of energy waste.

[1/] A degree-day is a unit used to predict seasonal fuel consumption for heating. For 1 day, the number of degree-days is equal to the number of degrees that the mean temperature for that day is below 65° F. For the heating season, the number of degree-days is the sum of degrees for all days that the mean temperature falls below 65° F. The average seasonal total of degree-days over a number of years is useful to estimate average annual heating costs for a given locality.

Optimum Thickness of Insulation

Minimum total costs result when first-cost of insulation plus the corresponding cost in energy over the useful life of the building are a minimum. A relatively simple engineering and cost analysis can be used to identify optimum thicknesses of any kind of insulation for local energy costs in any climate. This is no more than the same cost-effectiveness approach applied to many materials and types of equipment in industry and government. The method is commonly applied in heavy construction to many aspects of design, yet it has not been widely used in insulation design.

A survey of recent literature has revealed few published attempts to approach insulation design on a total cost basis. I made such a study involving cork insulation in a refrigerated building in 1947.[2/] The National Research Council of Canada initiated two such analyses in 1964 and 1965 (*2*, *11*). These excellent studies, however, are based on fuel and material costs which are now obsolete and do not consider the wide use of air conditioning in the United States.

Optimum Economy and Conservation

The design of insulation for optimum total cost economy, as applied in this study, does not at first seem to satisfy the objective of maximum conservation. Optimum conservation of energy would seem to imply maximum energy savings, perhaps regardless of costs. In fact, though, cost does enter the picture. As energy becomes less available, its cost will rise, and the development of new energy sources will very probably increase costs. As the cost of energy increases, so will the thickness of insulation needed to effect minimum total cost, and conservation automatically increases.

The economic method of insulation design presented here results in greater amounts of insulation and greater energy savings than previous methods. It is a practical method of obtaining maximum conservation which is economically realistic, as the fuel conserved per inch of insulation rapidly diminishes beyond the point of optimum economy. This can be readily seen in figure 1, where heat loss in a ceiling is plotted against insulation thickness. The heat saved by the 1st inch of insulation is 3 times that saved by the 2d inch and 75 times that saved by the 10th inch. Excessive quantities of insulation would quickly reach a point of no return, where the energy consumed in insulation manufacture, transportation, and installation, plus that which would be incurred by additional framing, exceeds the energy saved.

[2/] A. E. Oviatt. A frozen food locker plant. Unpublished B. Arch. thesis, Yale University, New Haven, Connecticut, 1947.

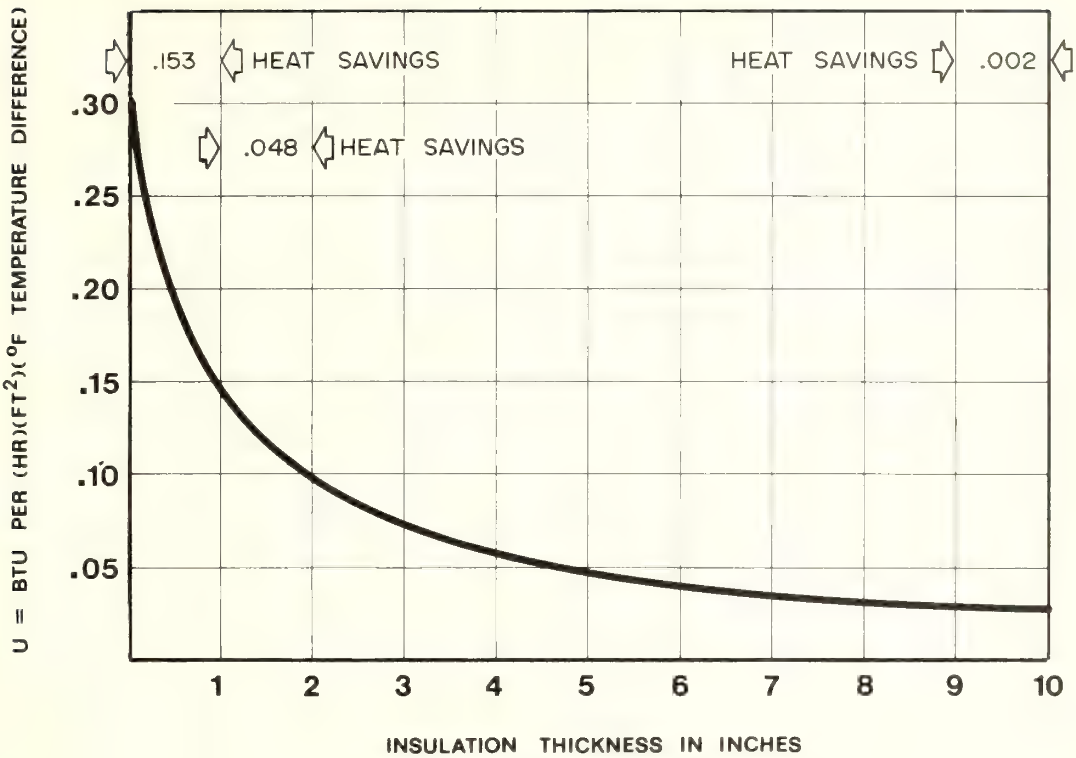

Figure 1.--Effect of increasing insulation thickness on heat losses in a typical roof-ceiling construction.

Method of Analysis

R. K. Beach of the National Research Council of Canada showed that optimum thickness of insulation can be obtained directly by an application of differential calculus familiar to many engineers (*2*). An equation for total cost must first be developed, including the many pertinent variables, and the first derivative taken to obtain a minimum cost expression. This may then be solved directly for optimum thickness. This method may be preferred by mechanical engineers who are able to develop and manipulate mathematical expressions for their particular area of practice. However, it has the disadvantage of being unintelligible to many architects, builders, and owners who are unfamiliar with the language of mathematics.

This report seeks to present visually the cost-thickness relationship for various areas, using graphs plotted from simple algebraic expressions. The basic engineering and cost relationships and assumptions used are outlined in the appendix, for those who wish to adapt them to special cases. Fuel costs are taken from the National Association of Home Builders Insulation Manual, 1971 (*5*), for the various local utilities. These costs are currently in a state of escalation at various regional rates, and their future levels cannot now be foreseen. However, possible future effects of inflation on insulation thickness are discussed.

Determing Heat Loss and Gain

The transfer of heat through a material or assembly of materials is measured by its *U* value, expressed in English units in Btu's per hour per square foot per degree Fahrenheit temperature difference between the two surfaces. This gives the heat loss through the construction for a unit area for each degree Fahrenheit temperature difference. Heat losses through each material in an assembly have a relationship based on reciprocals, as is the case in other areas of physics having to do with flow. To greatly simplify the summation of elements of a construction, an *R* value, signifying the resistance of an element or an assembly to the flow of heat, is now generally used. An *R* value is the reciprocal of the *U* value, and these resistance values may be directly summed for each element in a construction. When the total *R* is determined, however, it must be converted to its reciprocal or *U* value to return it to units of heat. *U* and *R* values used in this study, as well as engineering methods of computation, are taken from the authoritative American Society of Heating, Refrigerating and Air Conditioning Engineers "Handbook of Fundamentals" (*1*).

Heat transmission values for a typical wood-frame roof and ceiling construction are listed in appendix I. Although the nature of the construction has some effect on its *U* value, minor substitutions of materials have little ultimate bearing on the *U* value of a well-insulated construction. Thus, for example, it would make little difference whether the roofing is asphalt shingles, wood shingles, or slate, since the small change in *U* value for this element of the construction is dwarfed by the effect of the insulation itself. Similarly, the ceiling material might be gypsum board, plaster, or hardboard without materially affecting insulation requirements. But, if an insulating material, such as a 1-inch acoustical tile ceiling is made part of the construction, then the need for additional insulation would be reduced by nearly 1 inch. Some judgment is needed, therefore, in applying the results of this study to other constructions; but in most cases, variations in individual materials do not have a decisive effect on insulation requirements.

The amount of insulation in ceiling joists in an open attic may be limited by joist depth, due principally to the need to get full insulation depth over the entire ceiling at the eaves without blocking the usual eave ventilators. Normally, joist depths of over 8 inches would be uneconomical for structural purposes in a residential ceiling, so an insulation requirement of more than 7-1/2 inches net could increase construction cost somewhat by requiring deeper ceiling joists or a raised plate at the eaves. When greater insulation is required, as in areas along the northern border of the United States or in much of Alaska, a judgment must be made in trading the heat saving for the increase in construction cost. It may well be satisfactory in many cases to use a maximum of 7-1/2 inches of insulation, since an additional 1 inch, say, would have a negligible effect on heating cost in this range of total insulation thickness. The *U* values of a roof-ceiling system with no insulation and with 1 to 10 inches of insulation are given in tables 1 and 2 to extend total cost curves beyond the optimum point for all climates.

Table 1.--Heating and cooling costs per year per 1,000 square feet of ceiling (various locations)

Item	Insulation thickness (inches)										
	0	1	2	3	4	5	6	7	8	9	10
	Btu's per hour per square foot per degree Fahrenheit										
value construction	0.292	0.147	0.099	0.074	0.060	0.050	0.042	0.037	0.033	0.030	0.028
	Dollars										
st per year of insulation,)-year amortization	0	7.45	8.94	10.43	11.92	13.41	14.90	16.39	17.88	19.37	20.86
n Diego:											
Heating	13.15	6.45	4.33	3.20	2.63	2.19	1.84	1.62	1.45	1.32	1.23
Cooling	2.26	1.11	.75	.56	.45	.38	.32	.28	.25	.23	.21
Total	15.41	7.56	5.08	3.76	3.08	2.57	2.16	1.90	1.70	1.55	1.44
tal insulation and operation	15.41	15.01	14.02	14.19	15.00	15.98	17.06	18.29	19.58	20.92	22.30
attle:											
Heating	62.20	30.40	20.50	15.30	12.42	10.35	8.70	7.66	6.83	6.21	5.80
Cooling	.86	.42	.28	.21	.17	.14	.12	.11	.09	.09	.08
Total	63.06	30.82	20.78	15.51	12.59	10.49	8.82	7.77	6.92	6.30	5.88
tal insulation and operation	63.06	38.27	29.72	25.94	24.51	23.90	23.72	24.16	24.80	25.67	26.74
ami:											
Heating	4.05	1.98	1.34	1.00	.81	.68	.57	.50	.45	.41	.38
Cooling	60.00	29.40	19.80	14.80	12.00	10.00	8.40	7.40	6.60	6.00	5.60
Total	64.05	31.38	21.14	15.80	12.81	10.68	8.97	7.90	7.05	6.41	5.98
tal insulation and operation	64.05	38.83	30.08	26.23	24.73	24.09	23.87	24.29	24.93	25.78	26.84
. Louis:											
Heating	44.75	21.90	14.75	11.03	8.95	7.45	6.25	5.52	4.92	4.47	4.17
Cooling	39.90	19.55	13.15	9.85	7.98	6.65	5.58	4.92	4.38	3.99	3.72
Total	84.65	41.45	27.90	20.88	16.93	14.10	11.83	10.44	9.30	8.46	7.89
tal insulation and operation	84.65	48.90	36.84	31.31	28.85	27.51	26.73	26.83	27.18	27.83	28.75
icago:											
Heating	79.80	39.10	26.38	19.70	16.00	13.32	11.18	9.85	8.78	7.98	7.45
Cooling	23.40	11.46	7.72	5.77	4.68	3.90	3.27	2.88	2.57	2.34	2.18
Total	103.20	50.56	34.10	25.47	20.68	17.22	14.45	12.73	11.35	10.32	9.63
tal insulation and operation	103.20	58.01	43.04	35.90	32.60	30.63	29.35	29.12	29.23	29.69	30.49
lut!											
Heating	145.00	71.00	47.80	35.80	29.00	24.20	20.30	17.90	15.96	14.50	13.54
Cooling	.78	.38	.26	.19	.16	.13	.11	.10	.09	.08	.07
Total	145.78	71.38	48.06	35.99	29.16	24.33	20.41	18.00	16.05	14.58	13.61
tal insulation and operation	145.78	78.83	57.00	46.42	41.08	37.74	35.31	34.39	33.93	33.95	34.47
ntpelier:											
Total	168.00	82.20	55.30	41.30	33.60	27.90	23.50	20.70	18.47	16.80	15.66
tal insulation and operation	168.00	89.65	64.24	51.73	45.52	41.31	38.40	37.09	36.35	36.17	36.52

Table 2.--Heating and cooling costs per year per 1,000 square feet of ceiling (even inches of insulation thickness)

Item	Insulation thickness (inches)										
	0	1	2	3	4	5	6	7	8	9	10
	Btu's per hour per square foot per degree Fahrenheit										
U value construction	0.292	0.147	0.099	0.074	0.060	0.050	0.042	0.037	0.033	0.030	0.02[illegible]
	Dollars										
Cost per year of insulation, 40-year amortization	0	7.45	8.94	10.43	11.92	13.41	14.90	16.39	17.88	19.37	20.86
Energy cost index 41 (2 inches):											
Cost operation	12.30	6.02	4.06	3.03	2.46	2.05	1.72	1.52	1.35	1.23	1.15
Insulation and operation	12.30	13.47	<u>13.00</u>	13.46	14.38	15.46	16.62	17.91	19.23	20.60	22.01
Energy cost index 76 (3 inches):											
Cost operation	22.80	11.17	7.52	5.62	4.56	3.80	3.19	2.81	2.51	2.28	2.13
Insulation and operation	22.80	18.62	16.46	<u>16.05</u>	16.48	17.21	18.09	19.20	20.39	21.65	22.99
Energy cost index 124 (4 inches):											
Cost operation	37.20	18.23	12.28	9.18	7.44	6.20	5.21	4.58	4.09	3.72	3.47
Insulation and operation	37.20	25.68	21.22	19.61	<u>19.36</u>	19.61	20.11	20.97	21.97	23.09	24.33
Energy cost index 165 (5 inches):											
Cost operation	49.50	24.25	16.33	12.20	9.90	8.25	6.92	6.10	5.44	4.95	4.62
Insulation and operation	49.50	31.70	25.27	22.63	21.82	<u>21.66</u>	21.82	22.49	23.32	24.32	25.48
Energy cost index 228 (6 inches):											
Cost operation	68.30	33.50	22.60	16.87	13.70	11.41	9.58	8.43	7.52	6.83	6.38
Insulation and operation	68.30	40.95	31.54	27.30	25.62	24.82	<u>24.48</u>	24.82	25.40	26.20	27.24
Energy cost index 332 (7 inches):											
Cost operation	99.60	48.76	32.83	24.55	19.92	16.60	13.93	12.27	10.94	9.96	9.30
Insulation and operation	99.60	56.21	41.77	34.98	31.84	30.01	28.83	<u>28.66</u>	28.82	29.33	30.16
Energy cost index 427 (8 inches):											
Cost operation	128.00	62.70	42.20	31.60	25.60	21.30	17.90	15.78	14.08	12.80	11.94
Insulation and operation	128.00	70.15	51.14	42.03	37.52	34.71	32.80	32.17	<u>31.96</u>	32.17	32.80

Note: Minimum costs for each energy cost index are underlined to indicate corresponding insulation thickness.

Transmission values for a typical wood-framed wall construction are given in appendix II. These are calculated for an uninsulated wall and with insulation of 1 to 7 inches as listed in tables 3 and 4. Again, minor differences in wall materials would have little effect on the amount of insulation needed, unless such substitutions included such insulating materials as insulation board sheathing. It is important to note that a definite constraint on the thickness of insulation is imposed by the standard stud depth of 3-1/2 inches. To keep comparisons in the same terms, using only batt-type insulation in the stud spaces, any amount of insulation above 3-1/2 inches thick requires deeper studs, such as 2- by 6-inch or 2- by 8-inch. Although somewhat greater spacing between studs can be justified with deeper studs, significant increases in cost do appear here. These include the increased framing costs and an increase in the depth and cost of all window and door frames. These increased costs are added to insulation cost, as noted in appendix III, and do influence optimum economy. It should be noted, however, that no cost increase is assigned because of the loss in floor area attending a 2-inch increase in stud depth, as no practical method has been found to judge the economic effect of a small decrease in room dimensions in a residence. In many instances, this would have no real effect on the placing of furniture or the use of open spaces; and the common practice of assigning a cost per square-foot value, as in office space, is considered rather arbitrary and inapplicable in residential spaces. Any change in wall thickness, such as would occur with a change to masonry construction, for example, would affect interior area, but this is not normally assigned a value in residential cost comparisons. In individual cases, some allowance may be reasonable for the area factor, but no attempt has been made here to evaluate it for all cases.

It is thought important to note the effect of the framing members themselves on the overall resistance value of a ceiling or wall construction. Fortunately, wood framing members have a high insulating value, so that heat losses through them, bypassing the insulation, are relatively small. These heat losses have been considered in this study in appendixes I and II, though their effect on average *U* values is small and is often neglected for wood construction. As heat follows the path of least resistance, the major portion of the heat flow will not be through the entire depth of the framing member when some airspace is present. Therefore, a pattern of heat flow as shown in figure 2 has been assumed when insulation is not full depth.

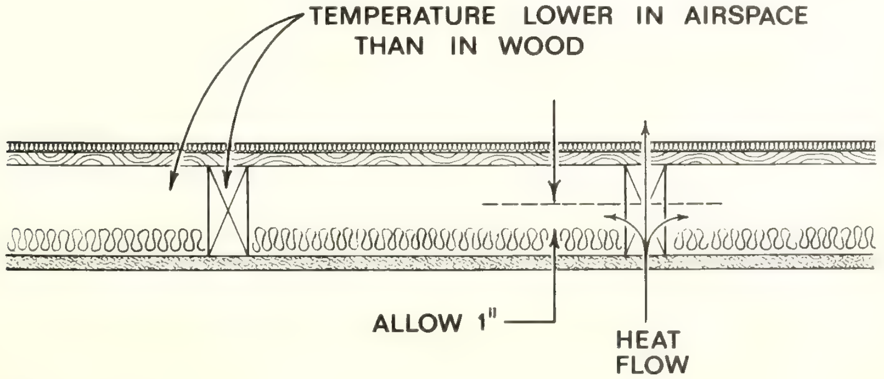

Figure 2.--Assumed heat flow through wood framing members when insulation is not full depth.

Table 3.--Heating and cooling costs per year per 1,000 square feet of wall (various locations)

Item	Insulation thickness (inches)							
	0	1	2	3	4	5	6	7
	- - - *Btu's per hour per square foot per degree Fahrenheit* - - -							
U value construction	0.250	0.136	0.093	0.071	0.059	0.051	0.043	0.039
	- - - *Dollars* - - -							
Cost per year of insulation--40-year amortization	0	7.45	8.94	10.43	11.92	13.41	14.90	16.39
Increased construction cost over 2 inches by 4-16 inches center to center	0	0	0	0	5.85	5.85	17.93	17.93
Total construction cost	0	7.45	8.94	10.43	17.77	19.26	32.83	34.32
San Diego:								
Cost heating and cooling	12.10	6.58	4.60	3.44	2.86	2.47	2.08	1.89
Total construction and operation	12.10	14.03	13.54	13.87	20.63	21.73	34.91	36.21
Seattle:								
Cost heating and cooling	52.10	28.30	19.80	14.80	12.30	10.62	8.96	8.12
Total construction and operation	52.10	35.75	28.74	25.23	30.07	29.88	41.79	42.44
St. Louis:								
Cost heating and cooling	58.40	31.80	22.20	16.60	13.80	11.93	10.05	9.12
Total construction and operation	58.40	39.25	31.14	27.03	31.57	31.19	42.88	43.44
Chicago:								
Cost heating and cooling	79.50	43.25	30.20	22.60	18.77	16.23	13.67	12.40
Total construction and operation	79.50	50.70	39.14	33.03	36.54	35.49	46.50	46.72
Duluth:								
Cost heating and cooling	121.20	65.80	46.00	34.40	28.60	24.70	20.80	18.90
Total construction and operation	121.20	73.25	54.94	44.83	46.37	43.96	53.63	53.22
Montpelier:								
Cost heating and cooling	137.70	75.00	52.30	39.10	32.50	28.10	23.70	21.50
Total construction and operation	137.70	82.45	61.24	49.53	50.27	47.36	56.53	55.82
Miami:								
Cost heating and cooling	33.85	18.44	12.86	9.62	8.00	6.91	5.83	5.28
Total construction and operation	33.85	25.89	21.80	20.05	25.77	26.17	38.66	39.60

Table 4.--Heating and cooling costs per year for 1,000 square feet of wall (various insulation thicknesses)

Item	Insulation thickness (inches)							
	0	1	2	3	4	5	6	7
	- - - *Btu's per hour per square foot per degree Fahrenheit* - - -							
U value construction	0.250	0.136	0.093	0.071	0.059	0.051	0.043	0.039
	- - - *Dollars* - - -							
Amortized cost per year insulation	0	7.45	8.94	10.43	11.92	13.41	14.90	16.39
Increased construction cost over 2 inches by 4-16 inches center to center	0	0	0	0	5.85	5.85	17.93	17.93
Total construction cost	0	7.45	8.94	10.43	17.77	19.26	32.83	34.32
Energy cost index 58 (2 inches):								
Cost heating and cooling	14.50	7.89	5.50	4.12	3.42	2.96	2.49	2.26
Operation and insulation	14.50	15.34	14.44	14.55	15.34	16.37	17.39	18.65
Operation, insulation, plus increased construction cost	14.50	15.34	<u>14.44</u>	14.55	21.19	22.22	35.32	36.58
Energy cost index 80 (3 inches):								
Cost heating and cooling	20.00	10.87	7.60	5.67	4.72	4.08	3.44	3.12
Operation and insulation	20.00	18.32	16.54	16.10	16.64	17.49	18.34	19.51
Operation, insulation, plus increased construction cost	20.00	18.32	16.54	<u>16.10</u>	22.37	23.34	36.27	37.44
Energy cost index 123 (3 inches):								
Cost heating and cooling	30.75	16.73	11.68	8.73	7.25	6.27	5.28	4.79
Operation and insulation	30.75	24.18	20.62	19.16	19.17	19.68	20.18	21.18
Operation, insulation, plus increased construction cost	30.75	24.18	20.62	19.16<u>*</u>	25.02	25.53	38.11	39.11
Energy cost index 490 (5 inches):								
Cost heating and cooling	122.50	66.60	46.50	34.80	28.90	25.00	21.07	19.10
Operation and insulation	122.50	74.05	55.44	45.23	40.82	38.41	35.97	35.49
Operation, insulation, plus increased construction cost	122.50	74.05	55.44	45.23	46.67	44.26<u>*</u>	53.90	53.42

Note: Minimum costs for each energy cost index are underlined to indicate corresponding insulation thickness. Asterisks indicate minimum costs are at full 3-1/2-inch or 5-1/2-inch thickness.

When metal framing members are used in an exterior wall, however, they have a very pronounced effect in shunting heat flow around fill-type insulation, so that appreciable reduction in the average resistance value occurs. In cold climates, vertical lines of condensation or frost can occur. When metal framing members are used in severe climates, any cavity insulation should be supplemented with enough insulation on the outside face of the framing to prevent condensation.

Determining Costs

The costs for heating and cooling for a unit area of a construction can be readily calculated from the expressions given in Appendix IV. It should be noted here that this study is concerned primarily with the insulation factor, not with other elements of a building which may contribute substantially to energy requirements. These elements may include windows, air leakage or air change, duct losses, and the heat added by occupants and appliances. Although very important in the entire economy of the heating system, they have no effect on the economical thickness of insulation in wall or ceiling areas. They will be considered as separate factors later.

The need for heating or cooling varies widely in the United States. Heating is not required in Hawaii, for example; and in the southern parts of Florida and Texas, small unit heaters are used only for short periods. When the degree-day heat requirement is less than 1,000 or so, the economical thickness of insulation for heating may approach zero. However, in most such cases, there is an appreciable cooling requirement, usually defined by the number of hours annually that temperatures reach or exceed 80° F. The cooling requirement may then control insulation requirements, as is true in Miami (fig. 3). Or the cooling requirement may have a large effect on insulation thickness, as in St. Louis (fig. 4). In San Diego (fig. 5) the combined costs of heating and cooling are so low that a small amount of insulation results in optimum total cost, and it can be argued that no added insulation at all is needed in wood-frame construction, since the total cost reduction is very small.

There may be little need for cooling in areas with mild summers, such as Alaska, Northwest coastal areas, and scattered areas at high altitudes. Seattle, for example, has an average of 100 hours per year with temperatures exceeding 80° F. Although the cooling cost per year is very low, the cost of cooling equipment becomes an important element in cost per hour of operation. A more economical method of cooling which uses less energy, such as an attic or window fan, may be a better choice here; or an evaporative type cooler, depending entirely on the evaporation of water, works well in arid areas, even when cooling requirements are high. Such a unit requires only enough power for fan operation for air distribution and has a much lower energy requirement than a refrigeration type unit. It does need a reasonable supply of water, sometimes in short supply in arid regions.

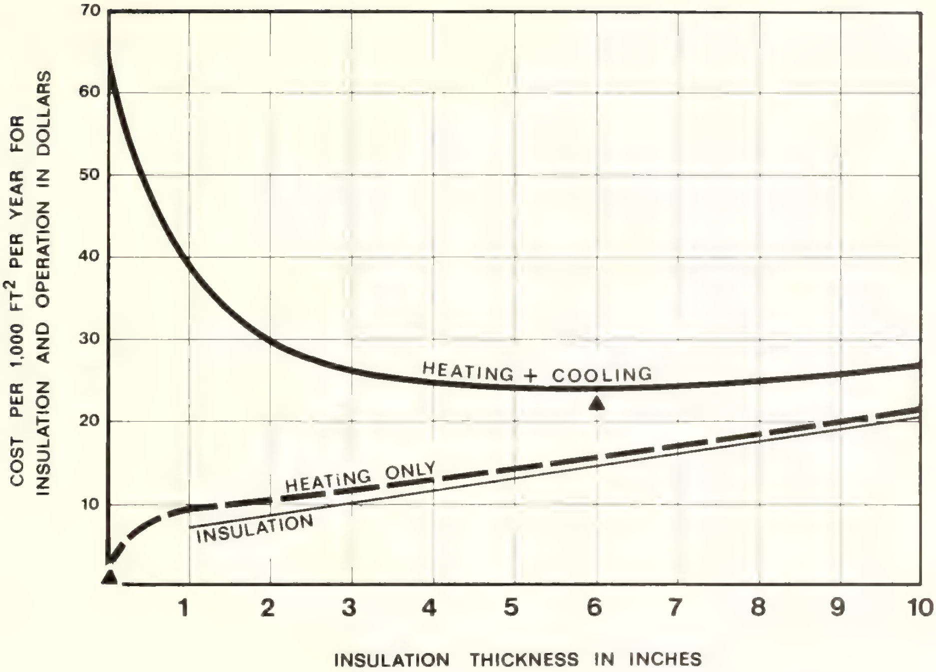

Figure 3.--Roof-ceiling insulation thickness determined principally by cooling cost (Miami).

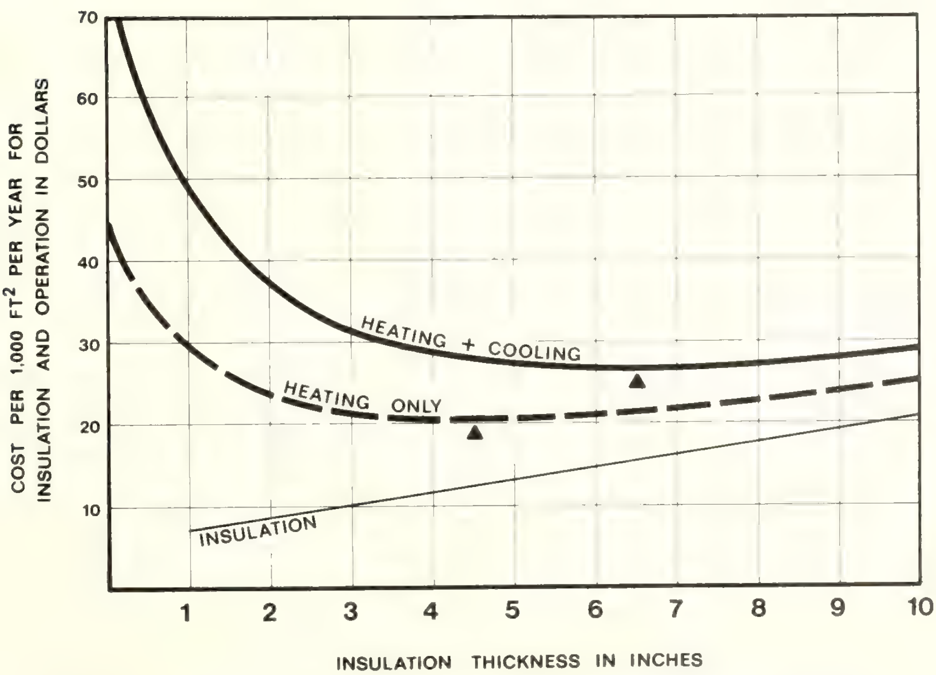

Figure 4.--Roof-ceiling insulation thickness as influenced by cooling cost (St. Louis).

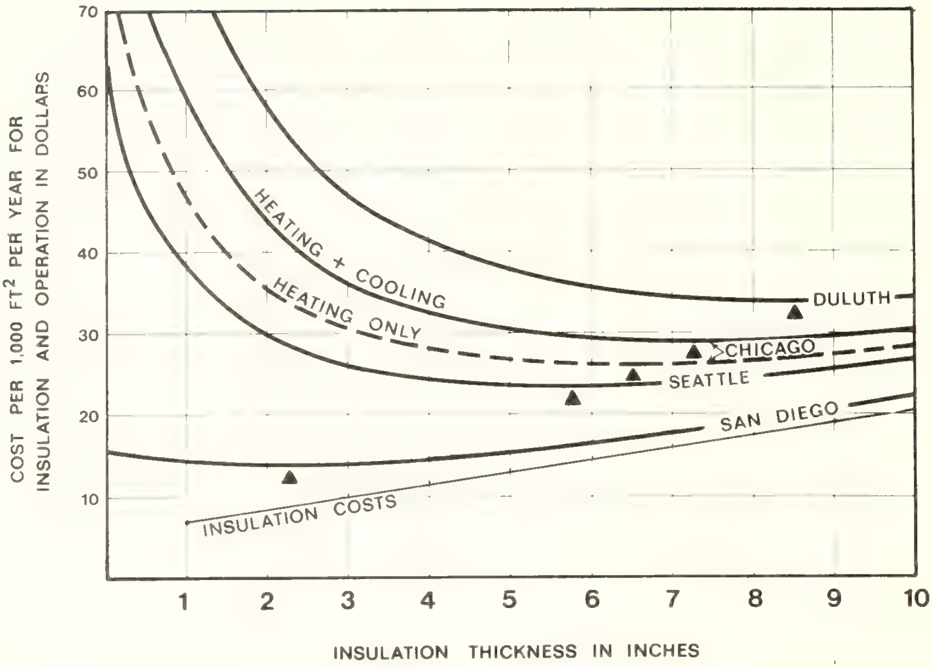

Figure 5.--Optimum roof-ceiling insulation thickness.

The cost of insulation in place, using mineral fiber blankets in the ceiling and batts in wall areas, was calculated with two sources of price data (*3*, *8*). These proved to be a good agreement, indicating a cost of \$0.10 per square foot for the first inch, and about \$0.02 per square foot for each additional inch. These costs are approximate average costs for the 48 contiguous States, with costs in Alaska and Hawaii undoubtedly higher. They are believed to be sufficiently accurate for this study.

When money is invested in a particular material in a home, it usually becomes part of a mortgage, at interest. However, it is of no consequence whether a mortgage actually exists, or what its duration may be. The sum so invested has a value, either in mortgage interest charged or in interest lost on a cash outlay over the entire useful life of the home. This hidden cost is large; and if calculated at a conservative 7 percent per year for 40 years, it has the effect of approximately tripling the original cost. This allowance for amortization is included in the tabulated and plotted costs of insulation, as well as of added stud, window frame, and door frame depths.

Total costs of operation and insulation are tabulated in tables 1 to 4 for all illustrated cost-thickness curves.

Total Cost Curves and Minimums

Cost-thickness curves in figures 3 to 5 for ceilings and figures 6 to 8 for walls are plotted from data in tables 1 and 3, respectively. Figure 5 indicates the optimum cost points on curves for ceiling insulation in four selected cities with varying heating and cooling requirements. Insulation cost is given by the sloping line at bottom, with heating and cooling costs added above to develop the total cost curves. For Chicago, total costs for heating only are indicated by a dotted line, and the addition of cooling increases optimum insulation by three-fourths inch. In Duluth, San Diego, and Seattle, cooling costs have almost no bearing on optimum thickness.

In Miami, though, cooling costs principally determine insulation thickness (fig. 3), and the dotted line indicates no need for insulation for heating alone.

The curves for St. Louis (fig. 4) show a more balanced condition, and the use of cooling would add 2 inches to the optimum insulation requirement for ceilings.

In frame-wall construction, figures 6, 7, and 8 show that generally less insulation is required in walls compared with ceilings. The significant increases in framing costs and frames for openings can be seen in the steps in these curves as the stud depth is increased. For the most part, increases from the standard 2- by 4-inch stud are not economically justified to increase insulation thickness in the continental United States, although a slight advantage is shown for the most severe climate in Montpelier, Vermont, if the loss in floor area is unimportant. San Diego, on the other hand, does not require wall insulation for economic reasons.

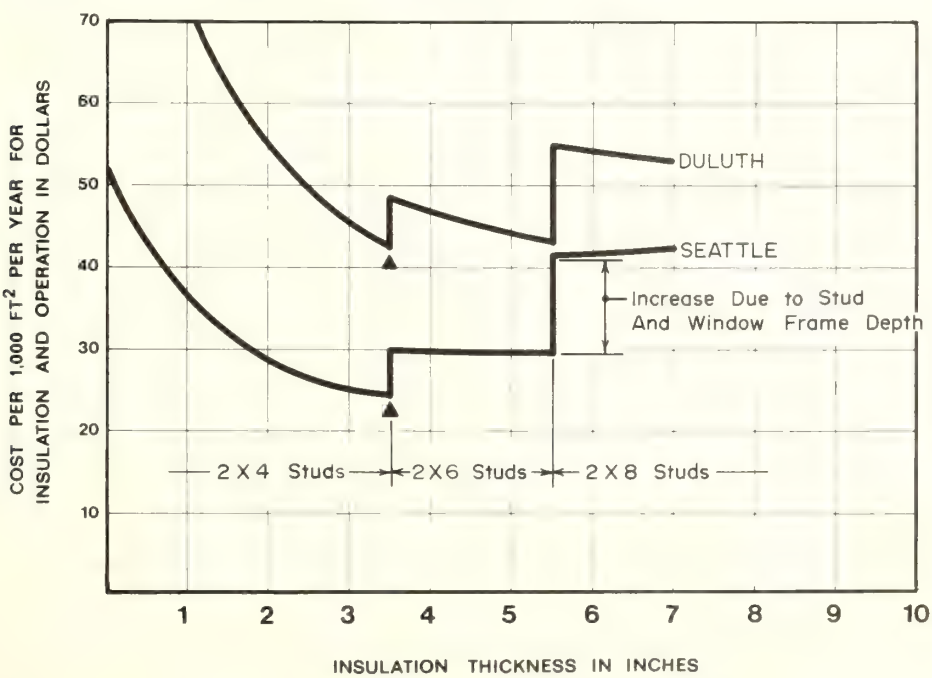

Figure 6.--Optimum thickness in walls.

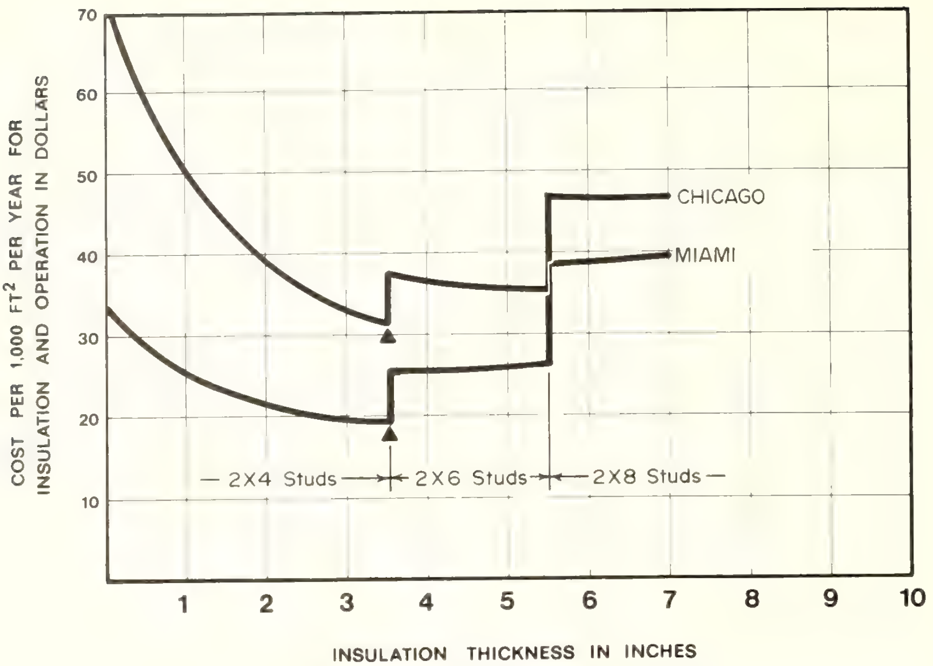

Figure 7.--Optimum thickness in walls.

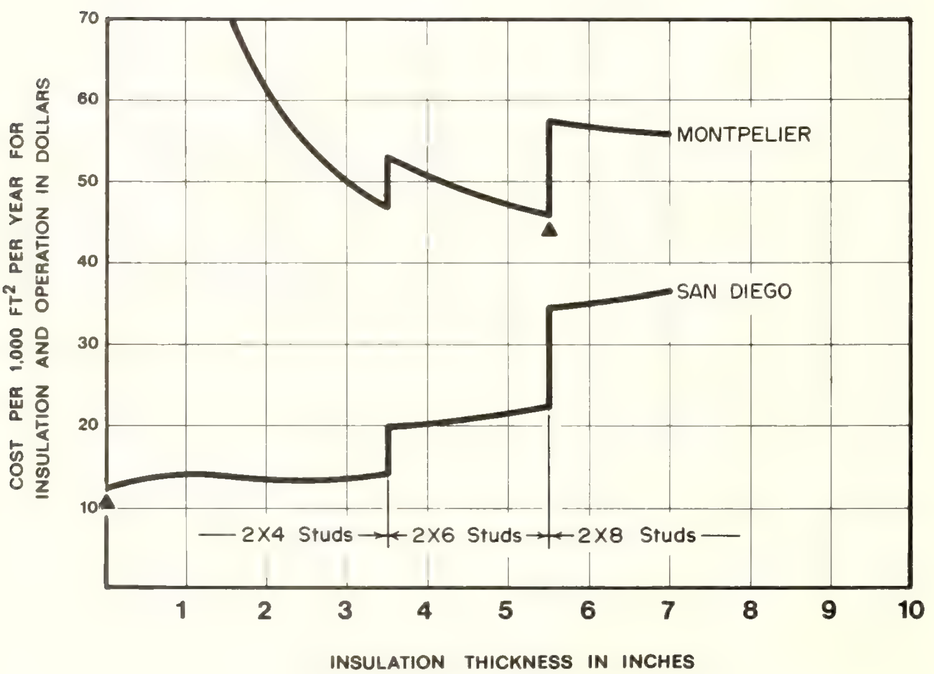

Figure 8.--Range of optimum thickness in walls--continental United States.

The use of 2- by 6-inch studs is not uncommon for the newer residences in many parts of Alaska. They can, in fact, be economically justified in regions with long, cold winters and little sunlight. Also, air change under these conditions is restricted to a minimum, and the moisture generated by humans and by cooking and other activities commonly make interior humidities high. This causes condensation and frosting at the studs, if they are not deep enough to keep the inside face of the wall above the dew point.

Influence of Inflation

Energy costs have increased appreciably since the oil embargo late in 1973. Subsequent increases in well-head costs for crude oil appear to be a continuing influence on our energy costs, and it is evident that our narrowing energy resources will result in gradually increasing costs for energy in all forms. With this outlook, should we not allow for an additional increase in insulation in homes?

Unfortunately, nobody knows how much energy costs may increase in the next 5 years, much less for the 40-year life of a new home. However, a look at the influence of increased costs on insulation requirements is useful, because balancing factors tend to stabilize the optimum economic thickness.

Figure 9 shows several curves for the thickness of ceiling insulation in St. Louis, based on various assumptions of cost changes. Curve A is the

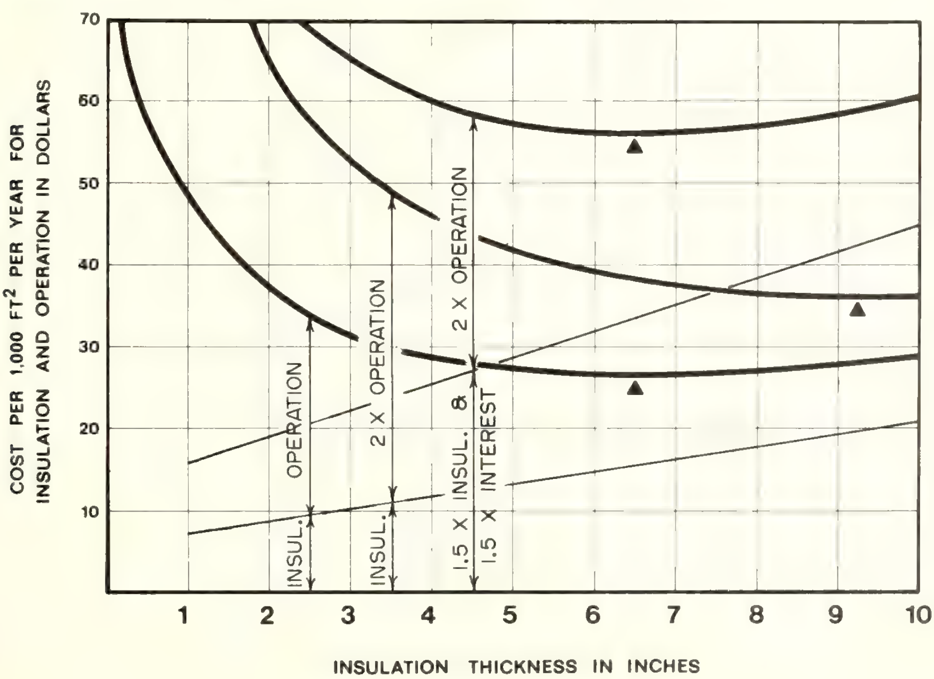

Figure 9.--Optimum roof-ceiling insulation thickness as influenced by inflation (St. Louis).

same as the total cost curve in figure 4, and the assumption here is one of complete stability of costs for energy, materials, labor, and money (which was assumed at 7-percent interest).

But if energy costs do escalate sharply, what happens to the insulation requirement? Curve B (fig. 9) is plotted on the assumption that energy costs will double over some period of time but that costs of insulation and money remain constant. This produces a marked shift in the point of optimum thickness, adding nearly 3 inches of ceiling insulation.

Of course, energy costs cannot increase in any such magnitude without affecting the costs of all manufactured goods, transporation, services, labor, and money. General inflation accompanies increased energy costs, as at present, and some portion of this inflation is directly attributable to the energy increase. Interest rates depend on the general inflation rate and rise proportionately.

Without pretending to know the future extent of energy costs or accompanying inflation in other costs, an example is shown in curve C (fig. 9) of the balancing effect of increased insulation and financing costs. Here the assumption is that at some future time costs of energy will double and costs for insulation and money will inflate at a lesser rate of 50 percent. This assumption results, coincidentally, in a return to about the same optimum thickness as in curve A, though at a higher cost level. Actually, although energy costs have doubled here, the amortized cost of insulation compounded has more than doubled, and a 50-percent increase in insulation cost and in interest rate (10-1/2 percent) results in a much larger total increase. A larger proportionate increase in amortized insulation cost as related to energy cost would, of course, reduce optimum insulation thickness; but this is not thought to be likely in the near future.

Our experience indicates that some degree of inflation will always be with us, and recent estimates of our energy resources strongly suggest that increases in energy costs in the future will exceed other inflationary factors. However, we need to consider the balancing effect of increases in other materials and in money, as illustrated in curve C (fig. 9). It is my opinion, therefore, that large increases in insulation thickness should not be provided in anticipation of increased energy costs. The cost-thickness curves characteristically are quite flat at the optimum cost point, and a change of an inch or more in thickness produces a very small change in total cost. Thus, some latitude exists in the choice of thickness. Also, an imbalance in inflationary trends will tend to stabilize optimum insulation thickness.

A reasonable approach, considering the foregoing factors, might be to choose insulation thickness to the next higher even inch above the apparent optimum, but judgment should be based on the particular conditions.

An Approximate Method of Estimating Local Energy Costs

We have considered some examples of optimum insulation thickness in various cities across the country. Let us now see how this analysis may be applied closer to home, in any selected area and in a simplified form.

For total cost of operation for heating and cooling for 1,000 square feet of ceiling or wall per year, the U[3] value of the construction is multiplied by the sum of local heating and cooling costs. If we regard this sum as an energy cost index (Ce) for the local area, then the total cost of operation for any given U value is equal to $U\ Ce$. It is useful to consider this quantity or cost index as an entity, as it contains all the factors that may vary with location. A simple expression from which this local cost index may be determined can be derived from the expressions given in appendix IV, thus:

$$Ce = 0.36\ D\ C_t + 0.146\ \Delta_T\ CH\ C_k$$

where

- Ce = energy cost index
- D = degree-days in heating season
- C_t = cost of natural gas in dollars per therm
- Δ_t = design equivalent sol-air temperature difference, degrees Fahrenheit
- CH = summer cooling hours per year
- C_k = cost of electricity in dollars per kilowatt-hour

This simplification applies only to natural gas heating and electric cooling, and assumes operating efficiencies for the gas heater of 0.67 and for the cooling unit of 2.0

The above expression, however, contains an element which may not be readily obtainable by a local owner or contractor. This is the quantity Δ_T, the design equivalent temperature difference, which takes into consideration the radiant effect of the sun on surfaces in the summer. This solar heat gain increases outside design temperatures considerably when the sun is shining, and its effect varies with location and the nature of the surface. The American Society of Heating, Refrigerating and Air Conditioning Engineers Handbook (1) lists these design equivalent temperatures in chapter 22, table 50, and explains their selection. Without this information, however, an intermediate value can be assumed with reasonable accuracy for residential design in most areas. Reasonable accuracy here means that optimum insulation thickness will be in error less than 1 inch plus or minus, even in areas of high cooling requirements such as Miami or Hawaii. However, for final

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[3] Defined on page 6.

design decisions in such hot and dry areas as Arizona, a competent professional should be consulted. If intermediate values of design equivalent temperatures of 38.0° F for ceilings and 20.5° F for walls are assumed, these approximate expressions for the energy cost index result:

Ceilings: $Ce = 0.36\ D\ C_t + (5.5\ CH\ C_k)$

Walls: $Ce = 0.36\ D\ C_t + (3.0\ CH\ C_k)$

The above formulas are for natural gas heating and electric cooling, as before. For No. 2 oil heating and electric cooling, they would become:

Ceilings: $Ce = 0.256\ D\ C_g + (5.5\ CH\ C_k)$

Walls: $Ce = 0.256\ D\ C_g + (3.0\ CH\ C_k)$

where: C_g = cost of heating oil in dollars per gallon.

The portion of the formulas in parentheses is the cooling cost index and, if no cooling is needed, may be omitted. With the assumed value of the design equivalent temperature, all elements of these expressions needed for estimating *Ce* may be obtained locally from utilities, oil dealers, or any competent heating and ventilating contractor.

Determining Optimum Insulation Thickness

Figure 10 contains a family of curves, based on the energy cost index, which covers the range of this index in the continental United States. These curves are for roof-ceiling construction and represent the energy cost indexes which correspond to inches of insulation thickness. Figure 11 is similar for walls, except that the cost indexes correspond to inches up to 3 inches, and actual stud depths of 3-1/2 and 5-1/2 inches. It should be kept in mind that insulation and other construction costs used in these illustrations are at 1973 levels which are believed not to have increased sufficiently to significantly alter the total cost curves at this writing. Energy costs used, however, are at 1971 levels and have increased in varying amounts in different areas. Fortunately, energy cost increases will automatically be reflected in the energy cost index, as locally computed, so that the curves remain valid but the energy cost index may increase. For èxample, a cost index for roof-ceiling construction in figure 10 computed at 228 for 6 inches of insulation might increase to 280 and indicate an optimum thickness of about 6-1/2 inches.

An example may help clarify how the energy cost index is calculated and used with the cost index curves to determine approximate insulation thickness. St. Louis has a high heating requirement along with a fairly high cooling requirement and provides a check on this simplified method of design when compared with the curve in figure 4, which was previously plotted by the longer method. St. Louis has an average degree-day heating requirement of 5,000 at a cost for natural gas of 0.0832 per therm. Summer cooling hours

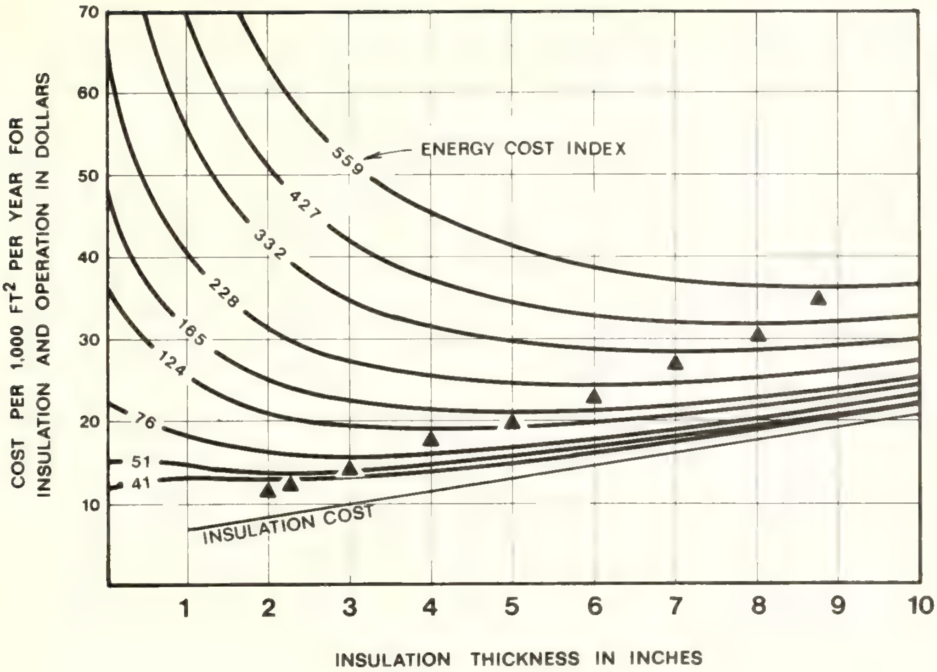

Figure 10.--Range of optimum roof-ceiling insulation thickness--continental United States.

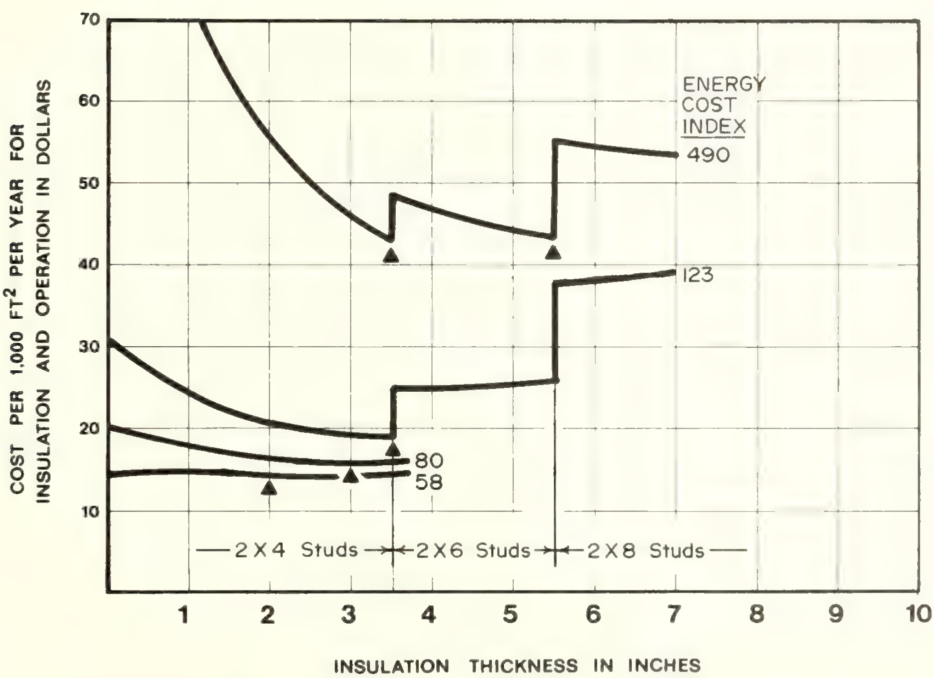

Figure 11.--Range of optimum wall insulation thickness--continental United States.

over 80° F are 1,150, and the cost of electric power is $0.0214 per kilowatt-hour. To obtain the energy cost index for a roof-ceiling construction, these values are substituted in the approximate formula for gas heat and electric cooling:

$$\begin{aligned} Ce &= (0.36)(5,000)(0.0832) + (5.5)(1,150)(0.0214) \\ &= 150 + 135 \\ &= 285 \end{aligned}$$

The cost index of 285 may then be interpolated between the curves for 228 and 332 in figure 10, and the imaginary curve about halfway between those shown would have a minimum total cost point at about 6-1/2 inches of insulation. This checks with the total cost curve in figure 4 and is the optimum insulation thickness for ceiling insulation in St. Louis. This may be increased to 7 inches to provide for future increases in energy cost.

Similarly, optimum thickness of insulation in any area can be determined by computing the energy cost index for the area and comparing it with curves in figures 10 or 11, for ceiling or wall insulation, respectively.

However, it is important to be aware of the limitations on accuracy of the method imposed by inflationary changes. Although energy cost index (*Ce*), as locally determined, will reflect energy costs at the time, there is no way to predict insulation cost increases. Therefore, the balancing effect of this factor is lost, and energy cost increases of 100 percent may indicate unreal thicknesses of insulation when applied to figures 10 and 11. For example, the cost of heating oil has doubled in the Seattle area in a little over a year. This nearly doubles the energy cost index for oil heat, since cooling is not an important element. A recalculation of the index will indicate an optimum thickness of insulation in the ceiling of 8 inches, with thickness in the walls remaining at 3-1/2 inches because of the extra costs attending an increase in wall thickness. This increase in the cost of heating oil is general in other areas and will operate to make an increase in insulation thickness economical in most northern areas. Costs of natural gas and electricity have increased at a lesser rate initially, and the increases vary in different areas, but it appears likely that they will eventually parallel increases in oil costs.

In some northern areas, energy cost increases may result in an energy cost index higher than the maximum curves shown in figures 10 and 11. When this occurs, I suggest maximum insulation thicknesses which do not incur increases in the framing; that is, 7-1/2 inches for ceilings and 3-1/2 inches for walls. This will result in a thickness very close to optimum in the continental United States and will avoid changes in the framing.

A Comparison of Design Methods

The foregoing method of selecting insulation thickness in a wood-framed home, based on optimum economy, generally results in a greater insulation requirement than methods previously in use. This can be seen in table 5, which compares the minimum thickness of ceiling insulation as determined by several criteria. The method using the difference between air temperature and inside surface temperature gives very inadequate thicknesses for the various locations, although a temperature difference of only 4° F was used here for a relatively high degree of comfort. The Industry All-Weather Comfort Standard results in a range of choices, obviously leaving this judgment to the local designer; but the high end of the range does not result in good economy in most areas. Only the new FHA Minimum Property Standards give reasonable economic thicknesses, though the accuracy of these standards is variable in different locations.

Table 5.--Minimum insulation thickness for a wood-framed ceiling construction under various criteria

(Inches)

Location	San Diego	Seattle	St. Louis	Duluth
Minimum comfort criteria, based on allowable ceiling temperature	1	1	2	3
Industry All-Weather Comfort Standard, National Forest Products Association	2-3	2-3	2-3	3-5
Federal Housing Administration Minimum Property Standards, 1974, new construction	3	5	5	6
Optimum economy (to next higher full inch)	3	6	7	9

Other Sources of Heat Loss

Heat loss and heat gain in a typical, uninsulated wood-framed house are not limited to that passing through wall and ceiling constructions, though the latter may amount to some 50 to 60 percent of total loss or gain. Other sources of loss include floor or ground, windows and doors, ventilators or cracks, and miscellaneous, such as may occur from ducts, chimneys, and water pipes. The relative percentage of loss occurring from each source, of course, will vary with areas involved and their insulation or sealing.

This study is principally concerned with the insulation of wall and ceiling areas, where optimum conditions of economy in typical constructions are possible. Other sources of loss are generally more difficult to analyze on a typical basis, as they may vary rather widely in individual cases and require local judgments. However, some discussion of these losses may emphasize their importance and guide the builder in their economical treatment.

GROUND LOSSES AND CRAWL SPACES

Several types of construction are used below the first floor of a home, either because of local practice or specific design advantages. With a full or partial basement, minimal heat losses to the basement occur in most climates, and the basement is warmed sufficiently for occasional use for laundry, workshop or storage, and to protect water pipes in extreme weather. Such a nominally unheated basement does not require insulation in the first floor. However, when the basement is designed for normal occupancy, floor and wall insulation may be required in the basement itself for economical heating. Heat transfer through basement floors and walls depends on their construction, ground temperatures at their outside surfaces, and the heat conductivity of the ground. The latter two factors are variable and may be unknown, and engineering assumptions based on local practice are usually necessary. Lower average wall temperatures in winter will normally require more insulation for walls than for floors. Because the temperature differences between outside and inside surfaces may not be accurately known over the heating season and because insulation costs are generally higher for masonry constructions, a determination of optimum amount is not practical. The objective for masonry walls should be to limit inside surface temperatures to comfort levels.

For concrete floor slabs in contact with the ground, experiments indicate that heat losses occur principally at the edges of the slabs and are negligible in interior areas. Therefore, insulation of the perimeter of the slab is sufficient to reduce heat loss to an economical level. In colder climates, as much as 2 inches of rigid insulation may be used around the perimeter, extending from the top of the slab, down the foundation, and under the slab about 2 feet. An alternate method used in milder climates is to place the insulation vertically on the outside of the foundation, extending from the top of the foundation to a point 6 inches below grade, using perhaps 1-inch thickness. Insulation placed in or on the ground in this manner must be waterproof, such as foamed plastic or glass board which does not absorb water. Slabs on the ground may usually be made comfortable enough for children's play by using 4 to 6 inches of gravel under the floor--also desired for moisture control--or by such floor surfaces as wood or thick pads and carpets. None of these measures may be needed, however, in milder southern climates where these slabs are most common.

Crawl space construction typically uses floor joists, supported by foundations and interior beams and posts, over a shallow excavation sufficient for access to heating ducts and pipes. A crawl space may be vented to the exterior the year around for moisture control, if ground moisture conditions are severe. However, control of ground moisture is usually possible with a ground cover of polyethylene sheet or roofing felts, so that the ventilating apertures in the outside wall may be closed off during the heating season.

When a closed crawl space can be used, insulation is not used in the floor, and ducts and hot-water pipes need not be insulated. Small amounts of heat from these sources keep the crawl space reasonably warm in mild winter climates and protect other piping. In severe winter climates, insulation may be needed; this is usually placed vertically on the inside of the foundation walls to limit heat loss. Again, plotting an optimum thickness for typical conditions is not possible, as average ground temperature, the proportion of the wall above grade, and kind of insulation will vary. The University of Illinois Small Homes Council (*10*) recommends 1 inch of foamed plastic or glass fiberboard for climates with an average outside air minimum temperature of -10° F or higher, with greater thickness desired for lower minimum temperature. A greater thickness may well be used to pack the header blocks at the ends of the joists to a depth equal to the optimum wall insulation thickness for the region.

When ground moisture conditions are severe, a crawl space may have to be vented continuously to control humidity and protect the structure. A ground cover can become ineffective if liquid water runs under it and through the laps; it then becomes a liability by retaining pools of water on the top as ground water recedes. Under these conditions, maximum ventilation is desired, and temperatures within the crawl space may approach that of the outside air.

In cold areas, water pipes should be insulated to prevent freezing, and heating ducts to limit heat loss. For comfortable floors and limited loss of heat from the area above, insulation in the floor structure is required. This is usually placed between the floor joists in the form of batts or blankets. In a new house, batts may be placed from above before the subfloor is laid, stapling flanges to the joists much as is done in walls. In existing construction, blankets may be placed from the crawl space, taking care that the moisture-barrier is up, and retained in place by spring clips, chicken wire, or other moisture resistant material nailed to the bottom of the joists.

Heat losses through a floor are not as great as losses through a ceiling, because the average inside-outside temperature difference is less. Average crawl space temperatures are moderated by ground temperature when there is little wind for ventilation and there is no solar load to provide for in summer cooling. Hence, insulation thickness in fully ventilated floors may be somewhat less than that of ceilings. For new construction where

insulation cost would be about the same in each case, I recommend use of optimum ceiling thickness for the climate, less 2 inches. This will result in a thickness close to the optimum for average open crawl space conditions.

STORM WINDOWS AND DOORS

Windows and doors account for a very high percentage of heat loss in a typical residence, which may be as much as 30 percent of the total heating and cooling load. The single-pane window is a particular problem, with very low resistance to the flow of heat through the glass and high transparency to radiant heat from the sun.

Windows, however, offer important amenities which outweigh problems of thermal control, furnishing daylight, ventilation, and an outward view. Windowless buildings have been designed and built but are not successful when continuous human occupancy is involved. Most building codes require that glass areas be at least 10 percent of floor areas, and the University of Illinois Small Homes Council recommends glass areas of at least 20 percent of floor areas (*9*).

Thermal problems related to windows may be greatly reduced by good design. Orientation to reduce solar loads is an important factor. If principal window areas face south, greater control of solar heat can be achieved by overhangs or solar shades which permit the entry of low winter rays but shade the window from the high summer sun. East and west windows are more difficult to shade in summer because of the sun's lower inclination, and loads are higher. Although drapes or venetian blinds may be used, these limit outward view and natural lighting. North windows take no advantage of winter sunlight, though they may be preferred in very hot climates to limit summer heating by radiation.

Horizontal windows high in the wall are often easier to shade than vertical windows extending lower. Moreover, they give better light from the sky with greater privacy and allow greater freedom in the placement of furniture.

Trees may be an important means of shading openings. Deciduous trees, in particular, have the advantage of shading in summer while allowing warming by the sun's rays in winter.

FHA Minimum Property Standards require that windows and doors in climates with more than 4,500 degree-days in the heating season be protected by double glazed units or storm windows and doors. This standard is reasonable in limiting energy use and in improving comfort as it is affected by radiation losses. Double glazed windows and doors or double doors of other material may reduce heat losses through openings some 40 percent. They do not, however, give optimum economy as these units do not fully recover their amortized cost in the 40-year useful life of a home in most areas of the United States.

For example, if the cost per square foot per year of a storm window, amortized as before, is compared with heating and cooling cost savings in Chicago, the cost of the window is not fully recovered in heat saved over a 40-year period. If a 3- by 5-foot storm window costs $40 and has about 15 square feet of glass area, this comes to $2.67 per square foot for the installation, amortizes to $8.01 at 7 percent, and gives a cost per year of $0.20 per square foot over 40 years. Energy savings for heating and air conditioning, determined by the difference in energy cost between the single window and the double sash, yields only $0.171 per square foot per year (see appendix V). Thus, about 47 years would be required to fully recover the storm window's cost.

It is important to note here, however, that the investment is by no means necessarily a bad one. It will effect a more comfortable interior environment, both in reduced radiant heat losses from the body during extremely cold outside weather and in increased acoustical privacy. It does this at a very small price, since most of the investment is returned in energy cost savings in 40 years, and it represents good energy conservation at the same small price. Also, inflation in energy costs may well greatly exceed inflation in other costs, a contingency that would improve the economy of the units.

Chicago has, of course, a rather severe climate with average heating degree days of 6,600. The example indicates an economic break-even point of some 7,500 degree-days for storm windows, but some north-central locations have as high as 10,000 degree-days, where the storm windows would pay for themselves in less than 40 years at current prices.

Similar cost comparisons can be shown for storm doors. Costs for sealed double glass windows and doors are generally higher than for single units plus storm sash, and the energy savings are about the same. However, the double glass units do offer greater convenience, as there is no interference with the unit's ventilating function and only two surfaces require cleaning. In new construction, particularly, they merit consideration because of these conveniences.

Reflective glass has been used for some years in air-conditioned commercial buildings to reduce solar heat gain. It can be obtained in single glass or sealed double glass units and deserves consideration in areas of high solar load.

AIR CHANGE AND INFILTRATION

Air leakage may account for very significant energy losses in a home. This usually occurs as infiltration around window and door units or leakage between the frames and wall surfaces and, of course, as doors are opened for entry or egress or windows are opened for ventilation. Other ventilating units, such as air conditioning systems, provide for variable amounts of air

change, as do kitchen or bathroom fan ventilators when in use. Cumulatively, these and other miscellaneous sources of leakage provide the air change necessary for health and for combustion of stoves or furnaces, but they usually do so at an unnecessary and excessive rate, wasting energy in the process.

Excessive ventilation by careless use of doors or windows is an obvious source of waste. Cracks around poorly fitted window sash or doors are major causes of unwanted heat loss or gain, particularly in older homes inadequately weatherstripped, or perhaps poorly adjusted or warped.

Permanent, metal or plastic channel weatherstripping of windows and doors is an economical device for reduction of the considerable energy lost through these cracks. It may often be installed by the homeowner and pays for itself in energy cost savings in a few years in most climates. Storm windows and doors reduce crack losses even when weatherstripping is not used, but additional reductions can be made by weatherstripping the inside unit. The storm unit should be less tightly fitted, since some ventilation to the outside is desired to limit condensation between the units. Crack losses can be reduced further if inside windows are kept locked, for the locking devices usually operate to pull sliding sash together or to tighten swinging sash to the frames.

MISCELLANEOUS LOSSES

Energy losses from ducts, pipes, and chimneys can be significant when they are inadequately insulated or sealed.

Hot or cold air ducts and returns which pass through unheated attics or open crawl spaces should be insulated with the equivalent of at least 1 inch of air-cell asbestos. Greater thickness is justified in extreme climates where the inside-outside temperature difference is large, and a 2-inch wrapping of mineral wool is common in northern locations. Steam and hot water pipes should be similarly covered when they pass through unheated spaces. In basements, ducts and pipes are frequently left uninsulated so that they contribute some heat to the basement area, but insulating cold water pipes to prevent dripping from condensation in the summer is desirable.

When heating ducts or radiant heating pipes or wires are incorporated in concrete slabs on the ground, the entire slab should be insulated from the outside walls and the ground, with moisture-proof insulation. When warm air perimeter ducts are used, it is satisfactory to limit the insulated area to the perimeter of the slab under the ducts, using at least 2 inches of insulation extending from the top of the slab, down the outside wall, and 24 inches under the ducts and slab.

Modern open fireplaces, commonly regarded as heating units, are insidious heat wasters. They are very inefficient, delivering little more than 10 percent of the energy generated to a room while pouring the larger portion of the heat up the chimney. Used in a home heated by other means, they draw much of the heated air from other parts of the house, reducing the effectiveness of the principal heater. They have a necessary function in places where other heating units may not be available and ample supplies of firewood exist, and they can be designed and located to yield a larger portion of their heat to a living area. In mild climates, they may also be a handy, occasional heat source when operation of a central heat source is not needed.

The fireplace today is a sentimental segment of tradition, emanating a cheerful, pleasant warmth to the family circle, while providing visual interest, lively sounds, and a pleasing aroma. These values cannot be measured in economic terms, and reasonable use of the fireplace is an individual choice. Moreover, it can be used as an indoor barbecue and is an excellent ventilator when large numbers of people are present.

Occasional use of the fireplace is least wasteful of heat when the room can be closed off from the rest of the dwelling to avoid drain on the central heater. A window may be opened a crack to provide draft within the room. If the fire is started sometime during the day or late afternoon and can be allowed to burn down early in the evening, it may be completely extinguished so the damper may be closed for the night. The damper should not be closed while any coals remain and very often is allowed to remain open all night to draw heat from the entire house. The fireplace damper should fit tightly, must be properly balanced so that the wind cannot open it, and should be kept closed when the fireplace is not in use. If a persistent draft is evident when the damper is closed, the fireplace opening may be closed off with a piece of plywood or other building board.

Conclusion

In summary, a lifetime cost analysis may be used in estimating insulation requirements in a wood-framed house. A simplified method of doing so for the principal wall and ceiling areas of a conventional home has been presented. This kind of analysis results in the best total economy for the homeowner and in maximum practical conservation of the energy used for heating and cooling. Increasing energy costs tend to demand greater amounts of insulation in buildings of all kinds, and all other sources of heat loss must be reexamined in terms of economy and minimum waste.

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APPENDIXES

Appendix I

I. Heat transmission values used for roof-ceiling construction

No insulation:

Construction	R value between rafters	R value at rafters
Outside surface (7.5-mi/h wind)	0.25	0.25
Asphalt shingles	.44	.44
Felt	.06	.06
1/2-inch plywood deck	.63	.63
Attic airspace	.90	.90
1/2-inch gypsum board ceiling	.45	.45
Inside surface (still air)	.61	.61
1-inch wood depth at rafter		1.25
Total R	3.34	4.59
U values = $\frac{1}{R}$ =	0.299	0.217

Rafters 24 inches o.c. (on center) cover 8 percent of ceiling area, and average U value is:

$$\frac{(0.299 \times 92) + (0.217 \times 8)}{100} = 0.292$$

*4-inch-thick insulation (example):

Total R construction	3.34	3.34
Add R 4-inch insulation	14.80	
Add R 5-inch-depth wood		6.25
Total R	18.14	9.59
U values = $\frac{1}{R}$ =	0.055	0.105

$$\text{Average } U = \frac{(0.055 \times 92) + (0.105 \times 8)}{100} = 0.060$$

*An average K value for mineral wool products of 0.27 (Btu's per hour per square foot per degree Fahrenheit temperature difference) has been assumed. This is equivalent to an R value of 3.70 for each inch thickness of insulation.

Appendix II

II. Heat transmission values used for wall construction

No insulation:

Construction	R value between studs	R value at studs
Outside surface (7.5-mi/h wind)	0.25	0.25
1/2-inch x 8-inch lapped siding	.81	.81
Building paper	.06	.06
1/2-inch plywood sheathing	.67	.67
3-1/2-inch airspace	.97	.97
Vapor barrier	0	0
1/2-inch gypsum board	.45	.45
Inside surface (still air)	.68	.68
1-inch wood depth at stud	____	1.25
Total R	3.89	5.14
U values $= \frac{1}{R} =$	0.26	0.20

Studs 16 inches o.c. cover 10 percent of wall area, and average U value is:

$$\frac{(0.26 \times 90) + (0.20 \times 10)}{100} = 0.25$$

*2-inch-thick insulation (example):

Total R construction	3.89	3.89
Add R 2-inch insulation	7.40	
Add R 3-inch-depth wood	____	3.75
Total R	11.29	7.64
U values $= \frac{1}{R} =$	0.089	0.131

$$\text{Average } U = \frac{(0.089 \times 90) + (0.131 \times 10)}{100} = 0.093$$

*An average K value for mineral wool products of 0.27 (Btu's per hour per square foot per degree Fahrenheit temperature difference) has been assumed. This is equivalent to an R value of 3.70 for each inch thickness of insulation.

Appendix III

III. Increased costs for stud depths greater than 3-1/2 inches

Cost increases were estimated using references *3* and *8* for the increased framing cost for 2- by 6-inch and 2- by 8-inch studs, on 24-inch centers, and for 2-inch increments in window and door frame depths, assuming an average amount of fenestration. Increases shown in tables 3 and 4 were:

	2-inch by 6-inch	2-inch by 8-inch
	(Dollars)	
Increased cost of stud framing per 1,000 square feet per year	1.05	8.33
Increased cost of window and door frames per 1,000 square feet per year	4.80	9.60
Total construction increase	5.85	17.93

Appendix IV

IV. Costs for heating and cooling

Cost of heating (natural gas) per year per thousand square feet:

$$\text{Cost} = U \times \frac{D \times C_t \times 24 \times 1{,}000}{100{,}000 \times E_g}$$

For No. 2 oil heating:

$$\text{Cost} = U \times \frac{D \times C_g \times 24 \times 1{,}000}{140{,}000 \times E_o}$$

For electric cooling:

$$\text{Cost} = U \times \frac{CH \times C_k \times \Delta_T \times 1{,}000}{3{,}413 \times E_e}$$

Symbols used above are:

U = coefficient of heat transfer of construction (Btu's per h per ft^2 per degree Fahrenheit temperature difference)

D = winter degree-days per year

CH = summer cooling hours per year

C_t = cost per therm of natural gas (dollars)

C_g = cost per gallon of No. 2 oil (dollars)

C_k = cost per kilowatt-hour of electricity (dollars)

Δ_T = equivalent sol-air temperature difference (degrees Fahrenheit)

E_g = efficiency of gas burner (0.67 assumed)

E_o = efficiency of oil burner (0.67 assumed)

E_e = efficiency of electric cooling unit (2.0 assumed)

Equivalents:

1 therm - 100,000 Btu's
1 gallon oil = 140,000 Btu's
1 kilowatt = 3,413 Btu's

Appendix V

V. Energy cost savings in Chicago from addition of storm windows (for this example, a window facing west is assumed, with roller shade half drawn)

Single window:

Heating cost per square foot per year =

$$U \times \frac{D \times C_t \times 24}{100{,}000\ E_g} = 1.13 \times \frac{6{,}600 \times 0.1123 \times 24}{100{,}000 \times 0.67} = \$0.30$$

Cooling cost per square foot per year =

$$D_s{}^* \times \frac{CH \times C_k}{3{,}413 \times 2.0} = 65 \times \frac{750 \times 0.0199}{3{,}413 \times 2.0} = 0.142$$

Total energy cost per square foot per year =

$$0.30 + 0.142 = \$0.442$$

Window with storm sash:

Heating cost per square foot per year =

$$0.56 \times \frac{6{,}600 \times 0.1123 \times 24}{100{,}000 \times 0.67} = \$0.149$$

Cooling cost per square foot per year =

$$0.56 \times \frac{750 \times 0.0199}{3{,}413 \times 2.0} = \$0.122$$

Total energy cost per square foot per year =

$$0.149 + 0.122 = \$0.271$$

Energy cost saving per square foot per year =

$$0.442 - 0.271 = \$0.171$$

Number of years required to amortize cost of storm window = $\frac{8.01}{0.171} = 47$

*D_s = design solar and conduction heat gain through windows. See "Handbook of Fundamentals" (*1*, chapter 22, table 51).

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Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

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Corvallis, Oregon	Wenatchee, Washington
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Experiment Station
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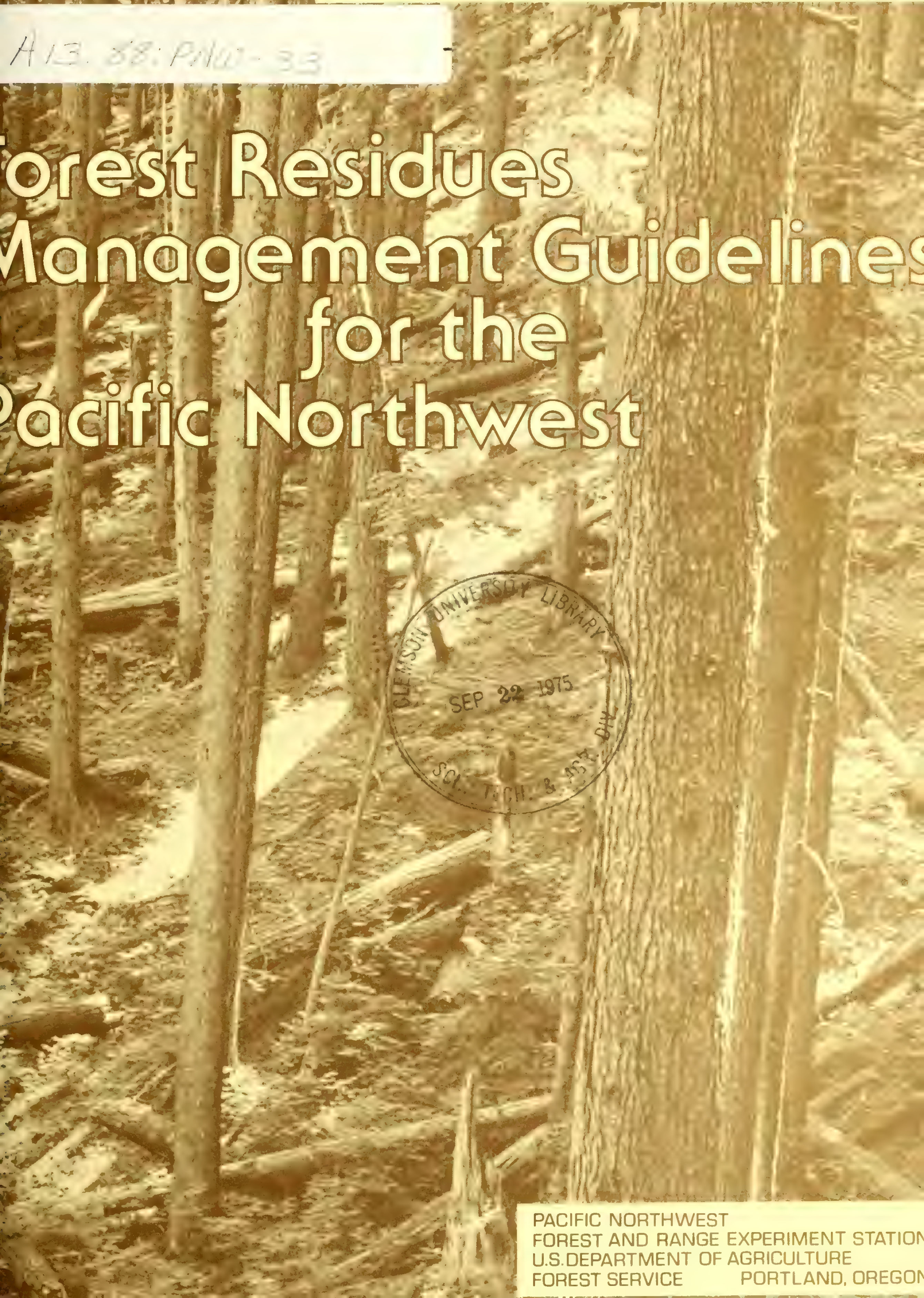
1975
USDA FOREST SERVICE GENERAL TECHNICAL REPORT PNW-33

A13.88:PNW-33

Forest Residues Management Guidelines for the Pacific Northwest



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ABSTRACT

Forest residues often require treatment to meet land management objectives. Guideline statements for managing forest residues are presented to provide direction for achieving these objectives. The latest research information and the best knowledge of experts in various land management disciplines were used to formulate these statements. A unique keying system is provided for determining which guidelines apply to a particular management activity, for a given site in a given location, and within a given forest species association type.

KEYWORDS: Forest residues, forest residue treatment, residue management.

See appendix 4 for metric conversion factors for measurements in this publication.

USDA Forest Service General Technical Report PNW-33

FOREST RESIDUES MANAGEMENT GUIDELINES FOR THE PACIFIC NORTHWEST

John M. Pierovich

Edward H. Clarke

Stewart G. Pickford

and

Franklin R. Ward

1975

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
Robert E. Buckman, Director — Portland, Oregon

FOREST SERVICE — U.S. Department of Agriculture

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key--out of reach of children and animals--and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U S DEPARTMENT OF AGRICULTURE

Foreword

Forest residues accumulate as a result of logging and natural mortality. When management is first introduced through harvesting of the overmature forests of the Pacific Northwest, huge volumes of residue--up to 300 tons per acre--have been measured after logging is completed. Most of this residue, in the form of branches, limbs, tops, broken chunks, cull sections, plus remnants of past natural mortality, is below prevailing minimum utilization and quality standards or is not economically attractive to the wood-processing industry. We must look toward future improvements in markets and in machinery and equipment for handling and transporting forest residues to encourage and achieve a greater degree of utilization and thus reduce the volume remaining onsite. Until such time, however, we are faced with the problem of managing these residues to achieve rapid regeneration in a manner that meets a wide range of environmental requirements for multiple-use forestry.

How best to manage these residues to meet environmental considerations while providing for the many goods and services of our forests is the subject of this publication. Old methods of treatment are being questioned; new ones are being evolved. Active public interest in all aspects of forest land management is manifest in the passage of significant legislation by Congress on multiple use of forest land and air and water quality, and in numerous court actions. Forest managers on both private and public lands share these concerns and are diligently developing forest practice guidelines, policy statements, and action plans to deal simultaneously with several major problem situations and with insuring the production of wood to satisfy the Nation's need.

Through the cooperation of representatives of Federal and State agencies, forest protection associations, forest industry groups, and both large and small private landowners, this publication was possible. These cooperators supplemented the knowledge available from research with their long and varied experiences to develop these guidelines. This report is more than just a treatment of environmental issues associated with the management of forest residues. It also is a product of a unique and effective way of organizing the needed skills for developing, disseminating, and applying research findings in a manner that encourages their acceptance and insures their fullest application.

Robert E. Buckman

ROBERT E. BUCKMAN
Director

Preface

The work of developing, organizing, and assembling these materials has been undertaken by foresters, scientists, and technical specialists from several agencies in many related disciplines, as well as by forest landowners. In a sense, it is a capsule of the experience and thinking of scores of source-document authors and correspondents, of 54 panelists serving on nine specialized technical panels, of 16 panelists on two land management decisions panels, and of seven special advisors to the panels. Several supporting research personnel helped with making references available. In addition, many individuals who helped with prepublication reviews have contributed their time, interest, and knowledge to this effort. (For actual participants, see appendix 1.)

The procedure followed may help others who wish to use a similar technique in developing management guidelines or policies where a synthesis of knowledge and experience is needed.

Briefly, the nine technical panels met concurrently and independently developed and recommended management guidelines oriented to their respective disciplines.[1/] For this task, they used "Environmental Effects of Forest Residues--A State-of-Knowledge Compendium" (Cramer 1974) and other reference material necessary to substantiate each guideline statement. The panel chairmen then resolved technical conflicts between statements originating in the different technical panels. Any conflicts not resolved, due to policy or other constraints, were referred to two land management decision panels, each comprised of line officers with long experience and major management responsibility.

One management panel represented public agencies and the other panel represented private industry and forest land managers. These panels arbitrated unresolved conflicts and accepted, rejected, or modified each recommended guideline statement to assure that each was administratively attainable.

Final responsibility for preparing this publication rested with the compilers. Our principal task was to combine, separate, and edit statements to common language, while preserving the original context as nearly as possible. We also helped resolve some technical or management conflicts. Finally, we devised a system for sorting the guideline statements according to categories representing combinations of geomorphic provinces, species associations, and management activities.

Although sponsored by the Forest Service, this work is not identifiable with any individual or any organization. It is a unique team product, made possible by phasing, by a high degree of cooperation, and by a strong motivation on the part of all participants.

1/ Air quality, diseases, fire management, insects, recreation, silviculture, soils, terrestrial habitat, and water quality and aquatic habitat.

CONTENTS

CONTENTS (continued)

Chapter I. About this publication

OBTAINING AN OVERVIEW

Unlike most guideline publications, this one is not written to be read from cover to cover. Unlike most guidelines, statements are not structured so as to allow indepth study for ways each may be applied. Instead, the user is urged to first read this chapter to get an overview and then to quickly sample various other sections of the report. The section on organization in this chapter will help with that sampling.

Once an overview has been obtained, the user is urged to become familiar with the unique way the guidelines are matched to specific land management situations. Chapter II is "home base" for this matching process and should be thoroughly understood before any attempt is made to evaluate the guidelines.

OBJECTIVES

The overall objective of this publication is to organize the best that is known about forest residue[1/] management into guideline statements for use by forest managers in the Pacific Northwest. The statements specifically are not a guide for intensive forest management practices on commercially operable forest lands. Rather, they assume that prudent forest management goals, objectives, and practices prevail--with respect to development, harvest, and regeneration of the forest--and that these activities are accomplished in a professional manner and with minimum disruption of the environment. They further assume that, although the utilization of residues has been maximized, some quantity requiring additional treatment remains. Thus, these guidelines are meant to direct management to achieve the biological or ecological objectives of the land manager, under the best available technology. They do not touch directly on financial feasibility, nor on economic goals of the land manager, although obviously, these are also important aspects of the land management job.

Therefore, the land manager must plan his activities with these aspects equally in mind. He must do the best he can with the budget and manpower at his disposal. This may mean stopping short of total achievement of objectives; for example, where additional incremental gains would come only at inordinately high incremental costs. In this larger sense, a quality job would require a blending of effort to meet both environmental and economic goals.

The reasons for undertaking this work may be grasped best if the many interactions and variations of response occurring in nature, the multiple uses of forest land, and the demands of economic and social forces are thought of as taking place in one large dynamic model. Land managers must constantly

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[1/] Along with other terms, "forest residue" is defined in the "Glossary."

attempt to integrate available knowledge about portions of this model to weigh the impact of alternatives on its operation. Often, the needed knowledge is only partially available--often, a generalization will encounter exceptions--yet decisions must be made.

To reduce the magnitude of generalizations about one portion of the model, forest residues, a unique system of localization has been used. Specificity and the most reasoned possible translations of knowledge into action terms have also been combined with a degree of risk-taking. The risks were taken when gaps in knowledge had to be bridged by use of experienced judgments to frame a suitable guideline statement. In taking these risks, we hoped a stimulus would be provided for aggressive new research and thereby these guidelines could be updated in the future.

A further objective has been to fully document the basis for each guideline statement so that both land managers and the public may draw upon common rationale.

HOW ORGANIZED

The three remaining chapters and six appendixes are organized in a scheme which recognizes the complexity of the material presented and anticipates that the user will turn directly to different segments as he searches for applicable management guidelines. The following is an overview of content in relation to this scheme.

Chapter II contains information essential to sorting guideline statements by activities and localities. Automatic data processing is suggested for large organizations intending to use these guidelines. This chapter also provides for use of these guidelines through manual sorting. As explained in the text, different colors of pages help the user turn rapidly to appropriate tables.

Chapter III contains separate guideline statements for public and private lands. This separation makes it important that the reader recognize that management goals are often different between public lands and private lands. Legislative, regulatory, and philosophical differences affect these goals as do differences in the need to operate forest ownerships sometimes for different social and economic purposes.

Chapter IV contains the documentation behind the guideline statements presented in chapter III. It presents supporting information from literature and from deliberations of the experts involved in developing these guidelines. Each guideline statement is referenced to the supporting information in this chapter.

The appendixes include additional supporting information for guideline statements as well as detailed acknowledgments.

Chapter II. Sorting procedures for guidelines application

INTRODUCTION

A land manager or user of these residue management guidelines cannot scan the 214 guideline statements and determine readily which few are appropriate to his situation. Rather, *he can only determine the application of these guidelines by a unique keying system which considers his planned management activity for a given site in a given location within a given species association type.*

This approach is necessary because only a very few broad general management guidelines can apply across all residue situations. To capture the full benefit of residue treatment objectives, the several factors which govern the choice and success of such treatments must be considered in structuring specific guidelines. For example, a species variable, such as thickness of bark, determines whether standing live trees can withstand a light prescribed underburning. Also, the depth, texture, angle of repose, and moisture content of soil have a significant bearing, not only on the amount of residue treatment, but on the choice of method.

Procedures presented in this chapter will deal with many other more complex combinations of biological, mechanical, and societal determinants.

SORTING PROCEDURES

Only a limited few of these guideline statements apply to every management situation. Most apply only to some given combination of a specific geomorphic province and a vegetative type. A few others apply only to special situations such as designated landscape management zones. Consequently, the only way to determine which guidelines appropriately apply to a given residue management situation is by a unique keying system.

Such a keying system can be designed for either automatic data processing or a manual sorting technique.

Automatic Data Processing

This system is recommended as best suited to an operational level in large organizations or firms where decisions are made for numerous timber sale contracts, slash disposal contracts, or work assignments, and other forest residue-related work. With this approach, a land manager would report sorting criteria to a central office (e.g., Rangers to Supervisors' Offices) and receive a printout of potentially applicable statements by return mail. Initial computer programing for the data processing system can be a straightforward matter adapted for a yes-no type of logic program. At the time individual guideline statements are stored in the system, any modifications needed to achieve conformance to agency policy can be made.

In addition to the obvious speed of obtaining a printout of applicable statements, this approach has the advantage of being easily updated when new laws, policies, or better knowledge dictate revisions of any statements.

Manual Sorting

When an automatic data processing system is not justified or not available, a manual procedure can provide a fairly rapid sorting of guideline statements. It cannot, however, lend itself as well to updating. Nonetheless, the following manual sorting procedure was developed so that immediate use can be made of these guidelines by any manager of forest land--large or small.

CRITERIA FOR MANUAL SORTING

The primary sorting is according to type of ownership--public lands or private lands. The secondary sorting is according to 16 management activities affecting residues. The additional sorting is according to Forest Residue Type Areas which divide Oregon and Washington into geographic units of like combinations of geomorphology and timber species associations.

Type of Ownership

Although there is common concern for the environmental effects of residue management, regardless of public or private ownership, there are some differences in management objectives which influence the applicability of residue management guidelines (see chapter III) to warrant sorting according to these two ownership groups. Thus, separate sorting tables are provided for public lands and for private lands in chapter III.

Management Activities

The 16 management activities considered in the development of these guidelines comprise 6 construction and 7 silvicultural operations and 1 each for treating natural residue, treating dying and damaged vegetation, and converting rangeland types.

For any planned forest operation involving two or more of these management activities, the manual sorting procedure requires a separate sorting for each activity. In this manner, two or more lists of guidelines which are applicable to the planned forest operation will be provided.

Forest Residue Type Areas (FR Types)

Both the geomorphology and the vegetative association of a location influence the creation and treatment of forest residues. The following forest residue type area classification scheme was synthesized from other classification schemes to simplify development and application of these guidelines. The FR Type Areas, as they will be called, are primarily geomorphic provinces, divided by timber species association and geomorphic subprovince. Figures 1 and 2 show these type areas for the Pacific Northwest.

A five-digit coding system is used for identifying the FR Type Areas. The first two digits represent the geomorphic province code. The third digit represents the timber species association code. The fourth and fifth digits represent the subprovince code.

```
            ___________Geomorphic Province
           |
           |           Timber Species Association
           |   ________
           |  /
          09 1  03
                 |
                 |_____Geomorphic Subprovince
```

In some cases, guideline statements have been identified by subprovince codes which do not appear in figures 1 and 2. These subprovinces were omitted ("00" as the last two digits in figures 1 and 2) when a significant area was not occupied by a commercial timber species, no management practice was anticipated that would create residue requiring treatment, and subprovinces were too scattered to be delineated clearly.

GEOMORPHIC PROVINCE CODES

01 Olympic Province

02 Coast Ranges Province

03 Siskiyou Province

04 Puget Sound Basin Province

05 Willamette Basin Province

06 Western Cascades Province

07 Northwestern Cascades Province

08 Northeastern Cascades Province

09 Recent (High) Cascades Province

10 Okanogan Highlands Province

11 Columbia Basin Province

12 Blue Mountains Province

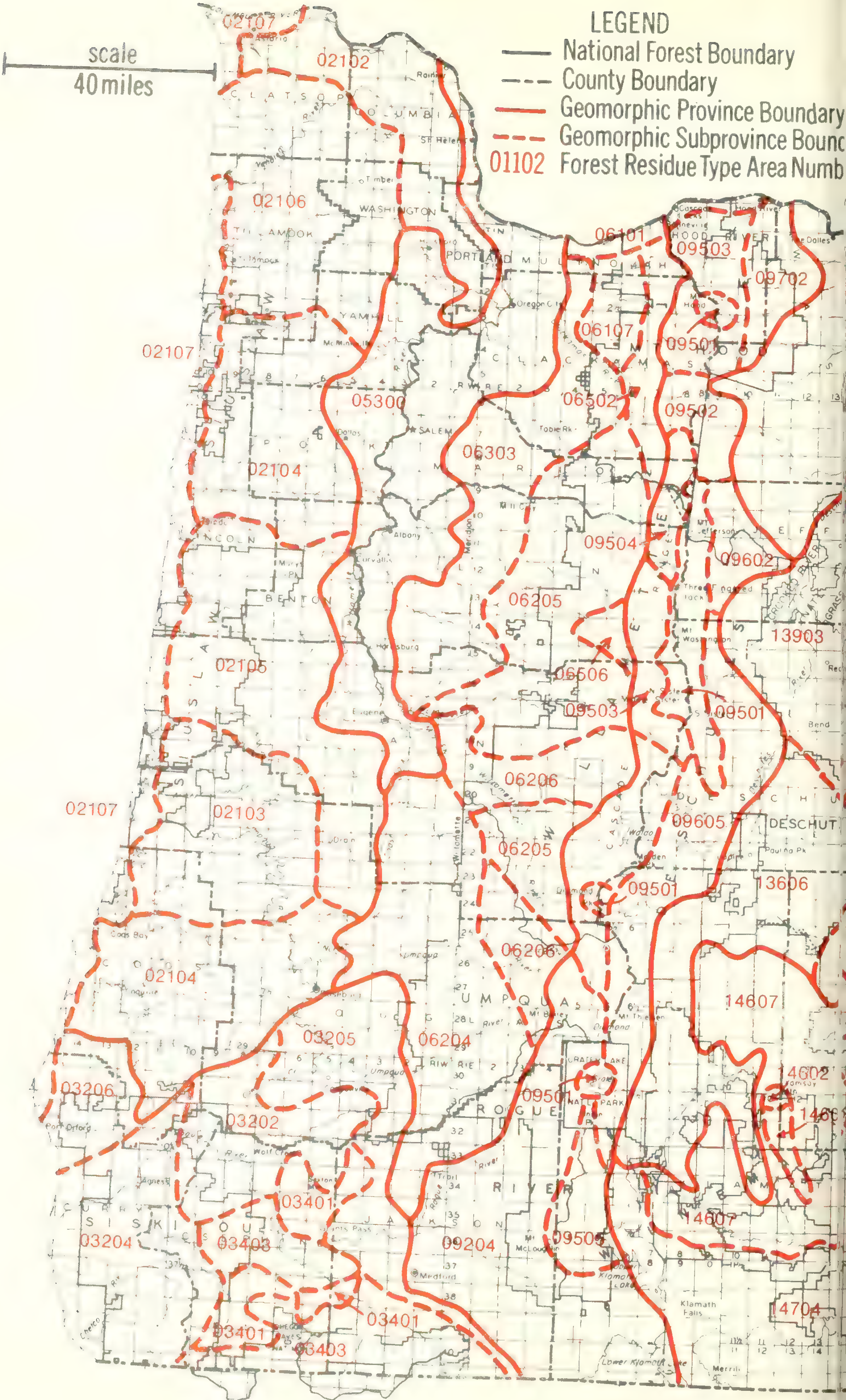
13 Harney Basin Province

14 Upper Basin and Range Province

15 Basin and Range Province

16 Cowlitz River Basin Province

17 Wallowas Province



LEGEND
National Forest Boundary
County Boundary
Geomorphic Province Boundary
Geomorphic Subprovince Bounc
01102 Forest Residue Type Area Numb
scale
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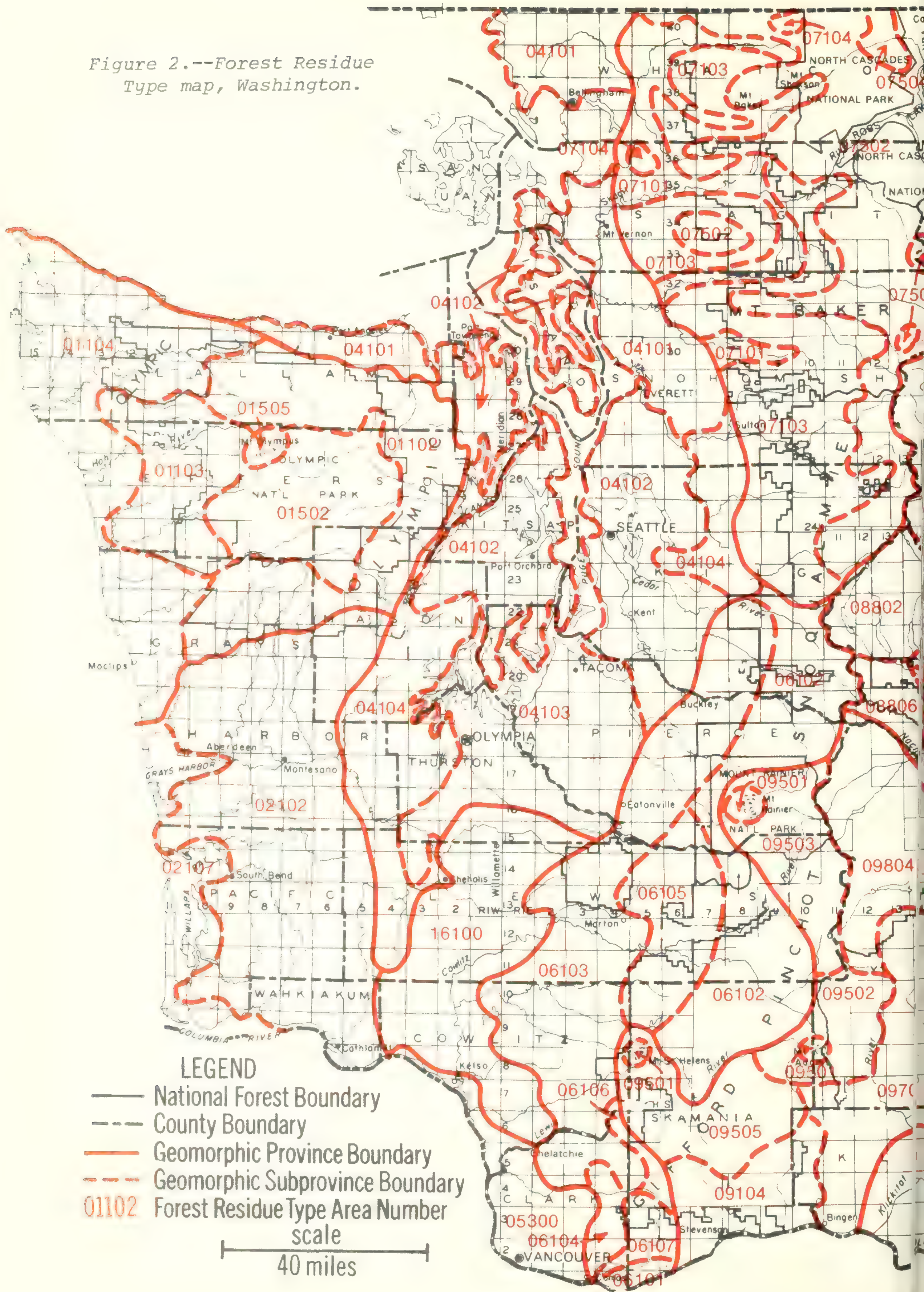
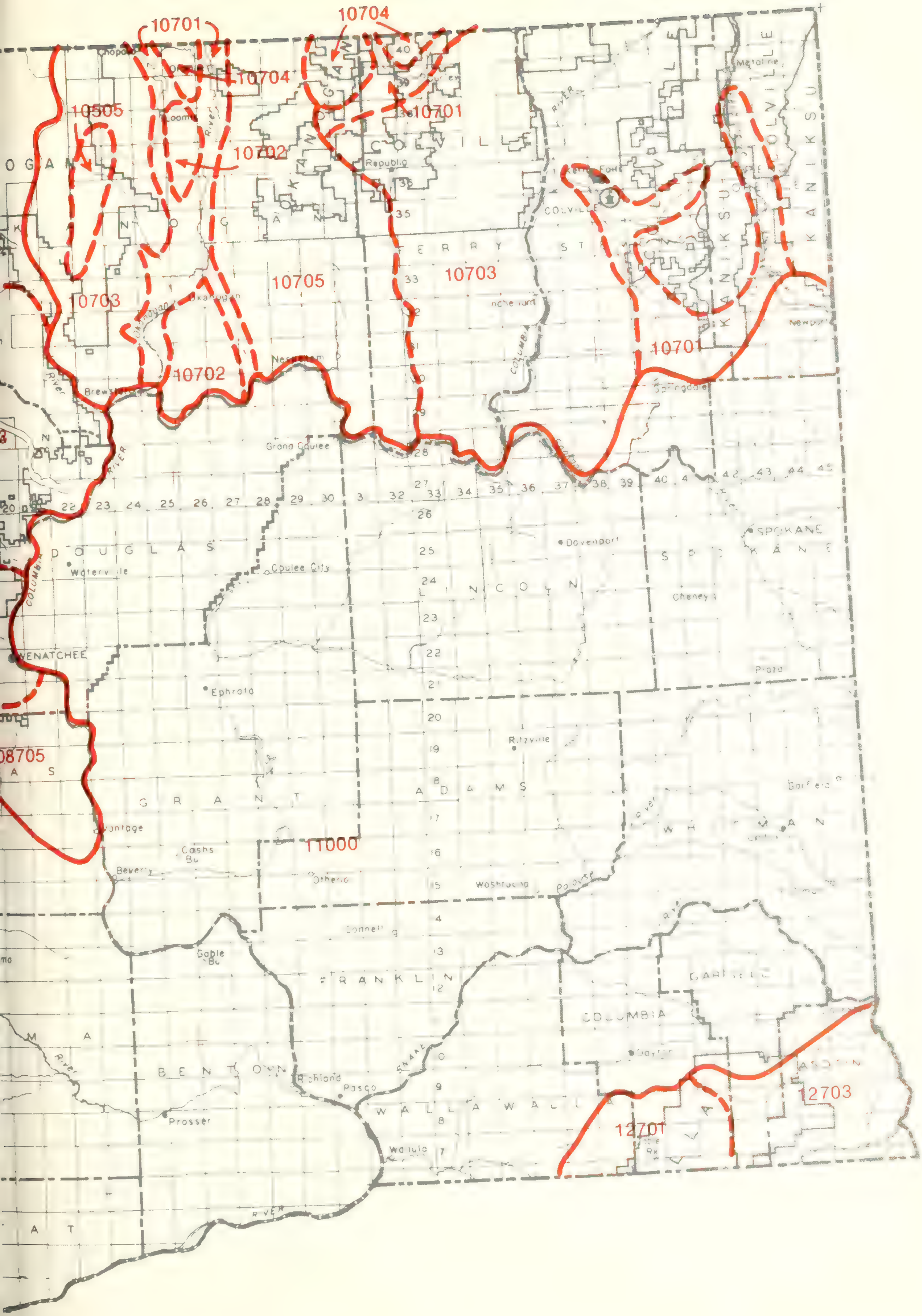
Figure 1.--Forest Residue Type map, Oregon.

Figure 2.--Forest Residue Type map, Washington.





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12701
12703
O G A N
Metaline
Republic
Okanogan
Nespelem
Brewster
COLVILLE
Kettle Falls
Newport
Springdale
Grand Coulee
Coulee City
Waterville
WENATCHEE
D O U G L A S
Ephrata
G R A N T
Davenport
L I N C O L N
SPOKANE
S P O K A N E
Cheney
Ritzville
A D A M S
W H I T M A N
Vantage
Othello
Washtucna
F R A N K L I N
GARFIELD
COLUMBIA
B E N T O N
Richland
Pasco
Prosser
W A L L A W A L L A
Wallula
ASOTIN
COLUMBIA RIVER
SNAKE

TIMBER SPECIES ASSOCIATION CODES

1 (Northern Douglas-fir)
Douglas-fir, western hemlock, western redcedar, grand fir, Pacific silver fir, red alder, Sitka spruce, bigleaf maple, western white pine

2 (Southern Douglas-fir)
Douglas-fir, western hemlock, incense-cedar, sugar pine, ponderosa pine, Port-Orford-cedar, Pacific madrone, tanoak, canyon live oak

3 (Willamette Valley)
Douglas-fir, ponderosa pine, western hemlock, Oregon white oak, bigleaf maple, California black oak, red alder, vine maple, Pacific dogwood

4 (Southwest Oregon Mixed Conifer)
Douglas-fir, sugar pine, tanoak, canyon live oak, Pacific madrone, golden chinkapin, ponderosa pine, incense-cedar, bigleaf maple

5 (Subalpine)
Mountain hemlock, noble fir, Pacific silver fir, subalpine fir, western larch, Engelmann spruce, western white pine, grand fir, Shasta red fir, ponderosa pine, Douglas-fir, lodgepole pine

6 (East-side Cascade Mixed Conifer--Pumice Soils)
Douglas-fir, ponderosa pine, lodgepole pine, western larch, incense-cedar, Engelmann spruce, sugar pine, mountain hemlock, grand fir, subalpine fir, western white pine

7 (Interior Ponderosa Pine/Lodgepole Pine)
Ponderosa pine, lodgepole pine, Douglas-fir, western larch, western juniper, grand fir, white fir, subalpine fir, Engelmann spruce, western white pine

8 (East-side Cascade Mixed Conifer--Nonpumice Soils)
Douglas-fir, ponderosa pine, western larch, Engelmann spruce, subalpine fir, mountain hemlock, grand fir, lodgepole pine

9 (Ponderosa Pine/Juniper Steppe)
Ponderosa pine, juniper, Douglas-fir, western larch

A description of the geomorphic provinces follows, plus a description and codes for the subprovinces within each, as well as the Timber Species Associations recognized within each province.

01 Olympic Province

The major portion of this province exhibits extensive glaciation. Main river valleys are broad and U-shaped, and major peaks are ringed with cirques, many containing active glaciers. Extremely high precipitation has caused rapid downcutting by streams and, with past glacial erosion, has created precipitous mountain slopes. These rugged mountains provide a central core surrounded by almost level lowlands which are the result of deposition of glacial outwash. Vegetation is characterized by extremely dense stands of Douglas-fir, western hemlock, and western redcedar, with Sitka spruce along the western edges.

Timber Species Associations recognized: 1 and 5

Subprovince number	Shown on map	Description
01	No	Glaciated, steep, long mountain slopes
02	Yes	Glaciated, steep, long mountain slopes
03	Yes	Glaciated, steep, long, dissected mountain slopes
04	Yes	Coastal plain
05	Yes	Snow-covered peaks and subalpine and alpine peaks

02 Coast Ranges Province

This province contains steep mountain slopes with ridges that are often extremely sharp. The ridge system is usually parallel to the coast but, being extremely dissected, is expressed subtly. The topography varies from nearly level along the dunal sheet through abrupt and steep lands along the western edges to more gentle lands along the eastern fringes. Scattered peaks, often barren, rise well above surrounding ridges. Vegetation is characterized by dense stands of Douglas-fir and western hemlock, with Sitka spruce and lodgepole (shore) pine along the western edges.

Timber Species Associations recognized: 1

Subprovince number	Shown on map	Description
01	No	Coastal headlands
02	Yes	Rounded dissected slopes
03	Yes	Short, highly dissected slopes
04	Yes	Steep, uneven mountain slopes and broad ridgetops
05	Yes	Complex of steep, dissected, and uneven mountain slopes
06	Yes	Steep, long mountain slopes
07	Yes	Dunal sheet, coastal headlands, and estuaries

03 Siskiyou Province

This province exhibits an ancient and now greatly dissected, uplifted plain; however, some peaks rise above the general accordant ridge. Vegetation reflects elements of the California north coast, and eastern Oregon flora with many

species indigenous only to the Siskiyou character type. Major communities are distributed in relation to moisture and elevation and include: pine-oak-fir, fir-broadleaved species, pine-fir-cedar-true firs, white fir, Shasta red fir, western hemlock, and Sitka spruce. This climatic diversity combines with a long history of disturbance, primarily fire, to produce an extremely varied array of communities.

Timber Species Associations recognized: 2 and 4

Subprovince number	Shown on map	Description
01	Yes	Drainage basin
02	Yes	Steep, uneven, dissected mountain slopes
03	Yes	Steep, long, mountain slopes
04	Yes	Steep, uneven, highly dissected mountain slopes
05	Yes	Steep, uneven mountain slopes
06	Yes	Steep, long, highly dissected mountain slopes

04 Puget Sound Basin Province

This province was subjected to massive continental glaciation, which formed an area of low relief broken by sounds, low moraine ridge systems and rounded hummocks, and many included lakes. Vegetation is characterized by Douglas-fir, western hemlock, western redcedar, and grand fir. Some stands of lodgepole pine are found on moraine remnants.

Timber Species Associations recognized: 1

Subprovince number	Shown on map	Description
01	Yes	Coastal plain
02	Yes	Morainal features with islands
03	Yes	Outwash plain
04	Yes	Rolling morainal deposits

05 Willamette Basin Province

This province reflects a structural depression with hills of low relief and alluvium deposited from ancient floods. The valley floor slopes very gently to the north and is interspersed with sluggish streams with many meanders. The natural vegetation mosaic consists of grasslands, oak woodlands, coniferous forest, and streambank (riparian) communities.

Timber Species Associations recognized: 3

Subprovince number	Shown on map	Description
01	No	Recent flood plain
02	No	Lacustrine plains
03	No	Foothills
04	No	Steep, short mountain slopes

06 Western Cascades Province

This province is composed of a slightly folded and uplifted accumulation of weathered volcanic flows. The area is characterized by a general conformity in ridge crests separated by deep valleys with steep, highly dissected side slopes. In the southern portion of this province, major valleys are V-shaped. Throughout the entire province glacial features are evident but not pronounced. Vegetation is characterized by Douglas-fir, western hemlock, grand fir, and subalpine fir.

Timber Species Associations recognized: 1, 2, 3, and 5

Subprovince number	Shown on map	Description
01	Yes	Columbia River Gorge
02	Yes	Glaciated, steep, long mountain slopes
03	Yes	Foothills
04	Yes	Steep, dissected mountain slopes
05	Yes	Steep, long mountain slopes
06	Yes	Steep, uneven mountain slopes
07	Yes	Rolling plateau remnants

07 Northwestern Cascades Province

This province is composed of sharp, jagged peaks and deep valleys resulting mostly from alpine glaciation. A striking topographic feature is the approximately uniform elevation of the main ridgetops. Towering above these relatively even crests are two dormant volcanoes (Mount Baker and Glacier Peak) as well as several granitic peaks of exceptional height. Glacial features such as morainal deposits on side slopes are common. Main stream valleys also contain deep accumulations of glacial debris. Vegetation is characterized by western hemlock, Douglas-fir, grand fir, and subalpine fir.

Timber Species Associations recognized: 1 and 5

Subprovince number	Shown on map	Description
01	Yes	Glacial valleys
02	Yes	Glaciated, steep, long mountain slopes with snow chutes
03	Yes	Glaciated, steep, long mountain slopes
04	Yes	Alpine and subalpine and snowcapped peaks

08 Northeastern Cascades Province

This province exhibits glacial sculpturing which has created an area of great relief with steep-sided, very deep valleys and long finger lakes. The area is made up of granitic batholiths, folded and, in part, metamorphosed, and sedimentary rocks with ridgetops having approximately uniform crest elevations. Vegetation is characterized by subalpine fir, grand fir, Douglas-fir, western larch, and some ponderosa and lodgepole pine.

Timber Species Associations recognized: 5, 6, 7, 8, and 9

Subprovince number	Shown on map	Description
01	Yes	Glacial valleys
02	Yes	Glaciated, steep, long mountain slopes with snow chutes
03	Yes	Glaciated, steep, long mountain slopes
04	Yes	Alpine and subalpine and snowcapped peaks
05	Yes	Plateau remnants
06	Yes	Dissected mountain slopes
07	Yes	Tilted, dissected plateau land
08	No	Finger lake

09 Recent (High) Cascades Province

This province consists of a volcanic plateau capped by shield volcanoes, cinder cones, and other volcanic forms, all of which are in various stages of disintegration. It is essentially an area of gently sloping terrain, interrupted at intervals by glaciated channels in the major drainages. The area is dotted with

volcanic peaks and cones rising 150 to 5,000 feet above the surrounding landscape. Much of the area is mantled with pumice and volcanic ash. Vegetation is characterized by Douglas-fir, grand fir, subalpine fir, hemlock, and ponderosa and lodgepole pine.

Timber Species Associations recognized: 1, 2, 5, 6, 7, and 8

Subprovince number	Shown on map	Description
01	Yes	Alpine and subalpine and snowcapped peaks
02	Yes	Plateaus
03	Yes	Glaciated, steep, long mountain slopes with snow chutes (north half)
04	Yes	Glaciated, steep, long mountain slopes
05	Yes	Pumice-mantled outwash plain and dissected plateau with craters and lakes

10 Okanogan Highlands Province

This province reflects repeated continental glaciation, resulting in a generally rolling terrain of moderate slopes and broad, rounded summits. Scattered peaks rise 3,000 to 4,000 feet above the general terrain, dividing the area into several upland areas separated by a series of broad north-south river valleys. Vegetation is characterized by grand fir and Douglas-fir with larch and ponderosa pine. Arid grasslands (steppe) are present along the western and southern edges.

Timber Species Associations recognized: 5, 6, 7, 8, and 9

Subprovince number	Shown on map	Description
01	Yes	Glaciated valleys
02	Yes	Plateaus
03	Yes	Glaciated, steep, long mountain slopes
04	Yes	Glaciated, rolling mountain slopes
05	Yes	Low, rolling uplands and morainal features
06	No	Canyon lands

11 Columbia Basin Province

This province includes the Columbia River basalt plateau which was modified by glacial outwash floods and wind to form coulees, scablands, and rolling loess hills. Steep slopes are of limited occurrence and restricted to isolated basaltic buttes or canyons carved by some of the major rivers. Vegetation is characterized by ponderosa pine along the western edge, becoming grass-shrub to grass in the central and eastern portions.

Timber Species Associations recognized: None

Subprovince number	Shown on map	Description
01	No	Dissected basalt plateau land
02	No	Lacustrine plains
03	No	Coulees
04	No	Channeled scablands
05	No	Rolling loess hills
06	No	Outwash valleys
07	No	Folded basalt ridges
08	No	Outwash plain
09	No	Basalt plateau
10	No	Sand dunes

12 Blue Mountains Province

This province is composed of several ranges of mountains separated by faulted valleys, synclinal (downfolded) basins, canyon lands, and lava plateaus. Topographic relief in the mountains is highly variable with moderately steep side slopes common. Dissection of the lava plateaus has also created steep canyon side slopes. Vegetation is characterized by ponderosa pine, grand fir, Douglas-fir, some subalpine fir communities, and shrub-grass communities.

Timber Species Associations recognized: 5, 6, 7, 8, and 9

Subprovince number	Shown on map	Description
01	Yes	Dissected basalt and plateau land
02	Yes	Lacustrine plains
03	Yes	Dissected basalt plateau land
04	Yes	Steep, long mountain slopes
05	Yes	Subalpine and alpine and snowcapped peaks
06	Yes	Steep, short, dissected mountain slopes and basins
07	Yes	Steep, short, highly dissected rolling lands
08	Yes	Dissected rhyolite plateau land - transition forest
09	Yes	Badlands and dissected plateau remnants
10	Yes	Lacustrine plain and basin high desert
11	Yes	Canyon lands

13 Harney Basin Province

This province exhibits a young, relatively uniform expanse of lava flows of moderate relief and dotted with scattered cinder cones and lava buttes. Porous soils, resulting from pumice and ash falls, and bedrock under scanty rainfall produce many seasonal streams. Undrained basins, some dry and others with fluctuating levels, are common. Evidence of violent volcanic activity is abundant in the western portions, with the Paulina Peak shield volcano the dominant example. Outstanding examples of very recent lava flows are near Lava Butte and Fort Rock. Vegetation is characterized by ponderosa pine, lodgepole pine, grand fir, some Douglas-fir, juniper, grass-shrub, grass, and desert shrub communities.

Timber Species Associations recognized: 6, 7, 8, and 9

Subprovince number	Shown on map	Description
01	No	Rhyolite plateau land
02	No	Rhyolite plateau land, lacustrine basin--lakebeds, volcano
03	Yes	Pumice and ash mantled, cinder cone, plateau land
04	No	Volcano-caldera
05	No	Recent basalt flow
06	Yes	Pumice mantled plateau land

14 Upper Basin and Range Province

This province exhibits fault-block mountains enclosing basin with internal drainage at generally higher elevations than the main Basin and Range Province. These formations create predominantly horizontal profiles in mountain silhouette with occasional cone-shaped features. Precipitation is moderate, occurring mostly as snow; most streams are perennial; and numerous undrained basins contain shallow lakes and marshes. Vegetation is characterized by mixed conifer, ponderosa pine, lodgepole pine, and grass-shrub communities. Unique are alpine and subalpine areas.

Timber Species Associations recognized: 6, 7, 8, and 9

Subprovince number	Shown on map	Description
01	Yes	Fault-block mountains, high elevation
02	Yes	Graben valleys
03	No	Rolling sagebrush lands
04	Yes	Dissected plateau lands, rolling sagebrush lands and lacustrine basin
05	No	Lacustrine basin--marshes
06	Yes	Fault-block mountains, lower elevation
07	Yes	Pumice-mantled rolling hills, high elevation alpine and subalpine

15 Basin and Range Province

This province consists of fault-block mountains with enclosed basins. Except for scarp slopes of the fault-block mountains, the area is rolling with low relief. Rainfall is scanty, most streams are intermittent, and numerous undrained basins contain shallow saline lakes. Vegetation is characterized by ponderosa pine, mixed conifer, lodgepole pine, grass-shrub, desert shrub, and juniper communities. Included in this province are alpine and subalpine areas.

Timber Species Associations recognized: 9

Subprovince number	Shown on map	Description
01	No	Alpine and subalpine
02	No	Lacustrine basin--lakebeds
03	No	Active sand dunes
04	No	Canyon lands
05	No	Fault-block mountain
06	No	Graben valleys
07	No	Rolling sagebrush land, low relief
08	No	Pumice-mantled plateau land

16 Cowlitz River Basin Province

This province reflects a structural depression occupied by the lower and middle Cowlitz River. Uplands of low rolling hills developed on volcanic materials are the dominant terrain feature. Lacustrine plains, terraces, and flood plains adjacent to the rivers occupy proportionately less area than in the Willamette Basin Province. The area has an overall southerly slope. The natural vegetation mosaic consists of conifers and hardwoods with heavy understory of mesophyllic shrubs and forbs.

Timber Species Associations recognized: 1

Subprovince number	Shown on map	Description
01	No	Flood plains
02	No	Outwash plains
03	No	Foothills
04	No	Steep, short mountain slopes

17 Wallowas Province

This province consists of a mountainous "island" surrounded by lava plateaus. These mountains are part of the Blue Mountains Province but are distinctive, since alpine glaciation has created a very precipitous and rugged mountainous area. The relief is much greater than in the Blue Mountains type. Vegetation is characterized by grand fir, Douglas-fir, subalpine fir, and mountain hemlock.

Timber Species Associations recognized: 5, 6, 7, 8, and 9

Subprovince number	Shown on map	Description
01	Yes	Alpine and subalpine and snowcapped peaks
02	Yes	Basalt plateau
03	Yes	Dissected basalt plateau
04	Yes	Glaciated, steep, long mountain slopes

TABLES

The following colored pages contain sets of tables to be searched for applicable guideline statement numbers. These tables were structured so that every guideline statement appears only for the specified FR Type Area(s) to which it applies. Thus, it may be possible that a given statement with across-the-board application appears in all tables and will sort out for all FR Types. Conversely, another statement will sort out only for the one FR Type to which it applies.

Two major sets of tables are provided: Those for Public Lands are printed on yellow and blue paper; those for Private Lands are printed on pink and green paper.

The yellow and pink pages (labeled Table Set I and Table Set II, respectively) each contain 16 sorting sets of tables. Each sorting set covers a different land management activity relating to forest residues creation and treatment, regardless of the FR Type.

The blue pages, labeled Table Set IA, and the green pages, labeled Table Set IIA, contain supplemental tabulations for verifying the applicability of each management activity related guideline to a specified FR Type Area. This cross-check is an important step in selecting only statements applicable to a given FR type from a large list of activity-related guideline statements evolving from the search process.

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET A

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
ROAD CONSTRUCTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.717	1.801	1.901	2.201	2.301		3.601	3.813
	1.718	1.802	1.902	2.202	2.302		3.607	
			1.903		2.303			
			1.904		2.306			
			1.905		2.307			
			1.906					

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101
1.102
1.103
1.104
1.105
1.106
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1.111
1.112
1.113

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.506	1.506	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507		1.516	1.515	1.514	
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.525	1.525	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517		1.525	1.524	1.523	
	1.525	1.527	1.527	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.518	1.518	1.518		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.522	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527					

SORTING SET A CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.723	1.719	1.719	1.719	1.720	1.719	1.719	1.720	2.401		1.727	2.401	2.402		1.719	1.719
2.401	2.206	1.721	1.721	2.401	2.206	2.401	2.401	2.401	2.402		2.401	2.407	2.407		2.401	2.401
3.602	2.401	2.401	2.401	2.408	2.401	2.402	2.402	2.402	2.407		2.402	2.408	2.408		3.603	2.402
	3.602	2.407		2.409	2.402	2.408	2.407	2.407	2.408		2.407	2.409	2.409			2.407
		2.408		2.410	2.407	2.409	2.408	2.408	2.409		2.408	2.410	2.410			2.408
		2.409			2.408	2.410	2.409	2.409	2.410		2.409	3.603	3.603			2.409
		2.410			2.409		2.410	2.410			2.410					2.410
		3.603			2.410			3.603			3.603					
					3.603											

NO GUIDELINES APPLICABLE IN THIS SET UNDER TABLE 5.

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET B

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
TRAIL CONSTRUCTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.717	1.801	1.901	2.201	2.301	3.607	3.809
	1.718	1.802	1.902	2.202	2.302		3.813
			1.903		2.303		
			1.904		2.306		
			1.905		2.307		
			1.906				

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101
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1.113

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.506	1.506	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507	1.503	1.520	1.515	1.514	1.526
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509	1.513	1.525	1.519	1.518	
	1.520	1.525	1.525	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.526	1.527	1.524	1.523	
	1.525	1.527	1.527	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.518	1.518	1.518			1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.522	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527					

SORTING SET 3 CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.728	1.719	1.719	1.719	1.720	1.719	1.719	1.720	2.401		1.727	1.738	2.402		1.719	1.719
2.401	1.738	1.721	1.721	2.401	2.206	2.401	1.738	1.738	2.402		1.738	2.401	2.407		2.401	2.401
	2.206	1.738	2.401	2.408	2.401	2.402	2.401	2.401	2.407		2.401	2.407	2.408			2.402
	2.401	2.401			2.402	2.408	2.402	2.402	2.408		2.402	2.408				2.407
		2.407			2.407		2.407	2.407			2.407					2.408
		2.408			2.408		2.408	2.408			2.408					

NO GUIDELINES APPLICABLE IN THIS SET UNDER TABLE 5.

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET 0

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
CAMPGROUND CONSTRUCTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.717	1.801	1.901	2.201	2.301	3.607	3.813
	1.718	1.802	1.902	2.202	2.302		
			1.903	2.203	2.306		
			1.904		2.307		
			1.905				
			1.906				

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101
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TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.517	1.517	1.517	1.506	1.506	1.517	1.517	1.517	1.504	1.504	1.517	1.506	1.517		1.521	1.515	1.514	
	1.521	1.521	1.521	1.508	1.517	1.519	1.519	1.519	1.508	1.508	1.518	1.517	1.518		1.527	1.519	1.518	
	1.527	1.527	1.527	1.517	1.519	1.521	1.521	1.521	1.517	1.517	1.521	1.518	1.521			1.521	1.521	
				1.519	1.521	1.524	1.524	1.524	1.513	1.518	1.523	1.521	1.523			1.524	1.523	
				1.521	1.524	1.527	1.527	1.527	1.521	1.521	1.527	1.523	1.527			1.527	1.527	
				1.527	1.527				1.522	1.523		1.527						
									1.527	1.527								

SORTING SET C CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.723	1.719	1.719	1.719	1.720	1.719	1.719	1.720	1.723		1.723	1.723	1.723	1.723	1.719	1.719
2.401	1.724	1.721	1.721	1.725	1.724	1.723	1.723	1.723	1.724		1.724	1.724	1.724	1.724	1.725	1.723
2.403	1.725	1.723	2.401	2.401	1.725	2.401	1.724	1.725	1.725		1.725	1.725	1.725	1.725	2.401	1.724
	1.728	1.724		2.408	2.206	2.402	1.725	1.738	2.401		1.727	1.738	2.402	2.406		2.401
	1.738	1.725		2.409	2.401	2.403	1.738	2.401	2.402		1.738	2.401	2.405			2.402
	2.206	1.738		2.410	2.402	2.408	2.401	2.402	2.405		2.401	2.405	2.406			2.405
	2.401	2.401			2.403	2.409	2.402	2.403	2.406		2.402	2.406	2.407			2.406
		2.403			2.407	2.410	2.403	2.405	2.407		2.405	2.407	2.408			2.407
		2.406			2.408		2.405	2.406	2.408		2.406	2.408	2.409			2.408
		2.407			2.409		2.406	2.407	2.409		2.407	2.409	2.410			2.409
		2.408			2.410		2.407	2.408	2.410		2.408	2.410				2.410
		2.409					2.408	2.409			2.409					
		2.410					2.409	2.410			2.410					
							2.410									

NO GUIDELINES APPLICABLE IN THIS SET UNDER TABLE 5.

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET 0

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
STRUCTURE CONSTRUCTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.801	1.901	2.201	2.301	3.601	3.813
	1.802	1.902	2.202	2.302	3.607	
		1.903	2.203	2.306		
		1.904		2.307		
		1.905				
		1.906				

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101
1.102
1.103
1.104
1.105
1.106
1.107
1.109
1.110
1.111
1.112
1.113

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.504	1.504	1.517	1.517	1.517	1.503	1.516	1.515	1.514	1.526
	1.521	1.521	1.521	1.519	1.519	1.519	1.519	1.519	1.517	1.517	1.516	1.518	1.518	1.513	1.521	1.519	1.518	
	1.527	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.518	1.518	1.521	1.521	1.521	1.526	1.527	1.521	1.521	
				1.527	1.524	1.524	1.524	1.524	1.521	1.521	1.523	1.523	1.523			1.524	1.523	
					1.527	1.527	1.527	1.527	1.522	1.523	1.527	1.527	1.527			1.527	1.527	
									1.527	1.527								

SORTING SET J CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
2.401	2.206	2.401	2.401	2.401	2.206	2.401	2.401	2.401	2.401		2.401	2.401	2.402	2.406	2.401	2.401
	2.401	2.406		2.408	2.401	2.402	2.402	2.402	2.402		2.402	2.405	2.405			2.402
		2.407		2.409	2.402	2.408	2.405	2.405	2.405		2.405	2.406	2.406			2.405
		2.408		2.410	2.407	2.409	2.406	2.406	2.406		2.406	2.407	2.407			2.406
		2.409			2.408	2.410	2.407	2.407	2.407		2.407	2.408	2.408			2.407
		2.410			2.409		2.408	2.408	2.408		2.408	2.409	2.409			2.408
					2.410		2.409	2.409	2.409		2.409	2.410	2.410			2.409
							2.410	2.410	2.410		2.410					2.410

NO GUIDELINES APPLICABLE IN THIS SET UNDER TABLE 5.

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET 2

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
SKI RUN CONSTRUCTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.717	1.801	1.901	2.201	2.301	3.607	3.804
	1.718	1.802	1.902	2.202	2.302		3.813
			1.903	2.203			
			1.904				
			1.905				
			1.906				

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101
1.102
1.103
1.104
1.105
1.106
1.107
1.109
1.110
1.111
1.112
1.113

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.512	1.517	1.517	1.506	1.505	1.507	1.510	1.510	1.503	1.508	1.505	1.506	1.507		1.516	1.515	1.514	
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.517	1.517	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.521	1.521	1.517	1.517	1.517	1.517	1.517	1.518	1.518	1.517	1.517	1.517		1.521	1.521	1.521	
	1.521	1.525	1.525	1.519	1.519	1.519	1.519	1.519	1.521	1.521	1.518	1.518	1.518		1.525	1.524	1.523	
	1.525	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.522	1.523	1.521	1.521	1.521		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.527	1.527	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527			1.527	1.527	1.527					

SORTING SET E CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.733	1.719	1.719	1.719	1.720	1.719	1.719	1.720	2.401		1.738	1.738	2.402		1.719	1.719
2.401	2.206	1.721	1.721	2.401	2.206	2.401	1.738	1.738	2.402		2.401	2.401	2.409		2.401	2.401
2.403	2.401	1.738	2.401	2.409	2.401	2.402	2.401	2.401	2.409		2.402	2.409	2.410			2.402
		2.401		2.410	2.402	2.403	2.402	2.402	2.410		2.409	2.410				2.409
		2.403			2.403	2.409	2.403	2.403			2.410					2.410
		2.409			2.409	2.410	2.409	2.409								
		2.410			2.410		2.410	2.410								

NO GUIDELINES APPLICABLE IN THIS SET UNDER TABLE 5.

TABLE SET 1
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET F

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
UTILITY RIGHT-OF-WAY

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.712	1.801	1.901	2.201	2.301	3.601	3.804
	1.713	1.802	1.902		2.302	3.606	3.805
	1.717	1.803	1.903			3.607	3.806
	1.718		1.904				3.812
			1.905				3.813
			1.906				3.814
							3.817
							3.818

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101
1.102
1.103
1.104
1.105
1.106
1.107
1.109
1.110
1.111
1.112
1.113

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.514	1.517	1.517	1.506	1.506	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507		1.516	1.515	1.514	
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.521	1.521	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517		1.521	1.521	1.521	
	1.521	1.525	1.525	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.518	1.518	1.518		1.525	1.524	1.523	
	1.525	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.522	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527					

SORTING SET F CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.716	1.715	1.714	1.719	1.720	1.719	1.719	1.720	1.723	3.807	1.723	1.723	1.715	1.723	1.719	1.719
2.401	1.723	1.719	1.719	1.725	1.724	1.723	1.723	1.723	1.724		1.724	1.724	1.723	1.724	1.725	1.723
3.602	1.724	1.721	1.721	2.401	1.725	2.401	1.724	1.725	1.725		1.725	1.725	1.724	1.725	2.401	1.724
3.605	1.725	1.723	2.401	2.408	2.206	2.402	1.725	2.401	2.401		1.727	2.401	1.725	2.406	3.603	2.401
	1.728	1.724		2.409	2.401	2.408	2.401	2.402	2.402		2.401	2.405	2.402	3.605	3.605	2.402
	2.205	1.725		2.410	2.402	2.409	2.402	2.405	2.405		2.402	2.406	2.405	3.807		2.405
	2.401	2.401		3.605	2.407	2.410	2.405	2.406	2.406		2.405	2.407	2.406			2.406
	3.602	2.406			2.408		2.406	2.407	2.407		2.406	2.408	2.407			2.407
	3.605	2.407			2.409		2.407	2.408	2.408		2.407	2.409	2.408			2.408
		2.408			2.410		2.408	2.409	2.409		2.408	2.410	2.409			2.409
		2.409			3.603		2.409	2.410	2.410		2.409	3.603	2.410			2.410
		2.410			3.605		2.410	3.603	3.807		2.410	3.605	3.603			3.605
		3.603					3.807	3.605			3.603	3.807	3.605			3.807
		3.605									3.807	3.808	3.807			
		3.807											3.808			

NO GUIDELINES APPLICABLE IN THIS SET UNDER TABLE 5.

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET 6

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
INDIVIDUAL TREE SELECTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.712	1.801	1.901	2.201	2.301	3.501	3.804
	1.713	1.802	1.902	2.202	2.302	3.506	3.806
	1.717	1.803	1.903		2.303	3.507	3.809
	1.718		1.904		2.306		3.813
	1.729		1.905		2.307		3.815
	1.730		1.906				3.816

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101	1.701	2.204
1.102	1.702	
1.103		
1.104		
1.106		
1.107		
1.109		
1.110		
1.111		
1.112		
1.113		

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.505	1.505	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507		1.516	1.515	1.514	
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.521	1.521	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517		1.521	1.521	1.521	
	1.521	1.525	1.525	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.516	1.518	1.518		1.525	1.524	1.523	
	1.525	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.522	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527					

SORTING SET 6 CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.716	1.715	1.714	1.719	1.720	1.719	1.719	1.720	1.723	3.807	1.723	1.723	1.715	1.723	1.719	1.719
2.401	1.723	1.719	1.719	1.725	1.724	1.723	1.723	1.723	1.724		1.724	1.724	1.723	1.724	1.725	1.723
2.403	1.724	1.721	1.721	2.401	1.725	1.731	1.724	1.725	1.725		1.725	1.725	1.724	1.725	2.401	1.724
	1.725	1.723	2.401	2.408	1.731	2.401	1.725	1.731	1.731		1.727	1.731	1.725	1.731		1.731
	1.728	1.724		2.409	2.206	2.402	1.731	1.732	1.732		1.731	1.732	1.731	2.406		2.401
	1.732	1.725		2.410	2.401	2.403	1.732	1.733	1.733		1.732	1.733	1.732	3.807		2.402
	1.735	1.731			2.402	2.408	1.733	1.738	2.401		1.733	1.738	1.733			2.405
	1.738	1.738			2.403	2.409	1.736	2.401	2.402		1.734	2.401	1.734			2.406
	2.206	2.401			2.407	2.410	1.738	2.402	2.405		1.738	2.405	2.402			2.407
	2.401	2.403			2.408		2.401	2.403	2.406		2.401	2.406	2.405			2.408
		2.406			2.409		2.402	2.405	2.407		2.402	2.407	2.406			2.409
		2.407			2.410		2.403	2.406	2.408		2.405	2.408	2.407			2.410
		2.408					2.405	2.407	2.409		2.406	2.409	2.408			3.807
		2.409					2.406	2.408	2.410		2.407	2.410	2.409			
		2.410					2.407	2.409	3.608		2.408	3.608	2.410			
		3.807					2.408	2.410	3.807		2.409	3.807	3.608			
							2.409				2.410	3.808	3.807			
							2.410				3.608		3.808			
							3.608				3.807					
							3.807									

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.704	1.707	1.703	1.703	1.705	1.705	1.703	1.703	1.707	1.707		1.703	1.707	1.707	1.707	1.705	1.707
1.706	1.708	1.704	1.704	1.709	1.708	1.707	1.707	1.709	1.708		1.706	1.708	1.708	1.708	1.709	1.708
	1.709	1.707			1.709		1.708		1.709		1.707	1.709	1.709	1.709		1.709
	1.711	1.708					1.709				1.708					
		1.709									1.709					

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TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET H

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
SHELTERWOOD CUTTING

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.712	1.801	1.901	2.201	2.301	3.501	3.804
	1.713	1.802	1.902	2.202	2.302	3.506	3.806
	1.717	1.803	1.903		2.303	3.507	3.809
	1.718		1.904		2.306		3.813
	1.729		1.905		2.307		3.814
	1.730		1.906				3.815
							3.816

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101	1.701	2.204
1.102	1.702	
1.103		
1.104		
1.106		
1.107		
1.109		
1.110		
1.111		
1.112		
1.113		

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.506	1.506	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507		1.516	1.515	1.514	
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.521	1.521	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517		1.521	1.521	1.521	
	1.521	1.525	1.525	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.518	1.518	1.518		1.525	1.524	1.523	
	1.525	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.522	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527					

SORTING SET H CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.716	1.715	1.714	1.719	1.720	1.719	1.719	1.720	1.723	3.604	1.723	1.723	1.715	1.723	1.719	1.719
2.401	1.723	1.719	1.719	1.725	1.724	1.723	1.723	1.723	1.724	3.807	1.724	1.724	1.723	1.724	1.725	1.723
2.403	1.724	1.721	1.721	2.401	1.725	1.731	1.724	1.725	1.725		1.725	1.725	1.724	1.725	2.401	1.724
3.602	1.725	1.723	2.401	2.408	1.731	2.401	1.725	1.731	1.731		1.727	1.731	1.725	1.731	3.603	1.731
3.604	1.728	1.724		2.409	2.206	2.402	1.731	1.732	1.732		1.731	1.732	1.731	2.406	3.604	2.401
	1.732	1.725		2.410	2.401	2.403	1.732	1.733	1.733		1.732	1.733	1.732	3.604		2.402
	1.735	1.731		3.604	2.402	2.408	1.733	1.738	2.401		1.733	1.738	1.733	3.807		2.405
	1.738	1.738			2.403	2.409	1.736	2.401	2.402		1.734	2.401	1.734			2.406
	2.205	2.401			2.407	2.410	1.738	2.402	2.405		1.738	2.405	2.402			2.407
	2.401	2.403			2.408	3.604	2.401	2.403	2.406		2.401	2.406	2.405			2.408
	3.602	2.406			2.409		2.402	2.405	2.407		2.402	2.407	2.406			2.409
	3.604	2.407			2.410		2.403	2.406	2.408		2.405	2.408	2.407			2.410
		2.408			3.603		2.405	2.407	2.409		2.406	2.409	2.408			3.604
		2.409			3.604		2.406	2.408	2.410		2.407	2.410	2.409			3.807
		2.410					2.407	2.409	3.604		2.408	3.603	2.410			
		3.603					2.408	2.410	3.608		2.409	3.604	3.603			
		3.604					2.409	3.603	3.807		2.410	3.608	3.604			
		3.807					2.410	3.604			3.603	3.807	3.608			
							3.604				3.608	3.808	3.807			
							3.608				3.807		3.808			
							3.807									

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.704	1.707	1.703	1.703	1.705	1.705	1.703	1.703	1.707	1.707		1.703	1.707	1.707	1.707	1.705	1.707
1.706	1.708	1.704	1.704	1.709	1.708	1.707	1.707	1.709	1.708		1.706	1.708	1.708	1.708	1.709	1.708
	1.709	1.707			1.709		1.708		1.709		1.707	1.709	1.709	1.709		1.709
	1.711	1.708					1.709				1.708					
		1.709									1.709					

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET J

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
GROUP SELECTION CUTTING

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.712	1.801	1.901	2.201	2.301		3.601	3.804
	1.713	1.802	1.902	2.202	2.302		3.606	3.806
	1.717	1.803	1.903	2.205	2.303		3.607	3.809
	1.718		1.904		2.306			3.812
	1.729		1.905		2.307			3.813
	1.730		1.906					3.814
								3.815
								3.816
								3.817
								3.818

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101	1.701	2.204
1.102	1.702	
1.103		
1.104		
1.106		
1.107		
1.109		
1.110		
1.111		
1.112		
1.113		

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.506	1.506	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507		1.516	1.515	1.514	
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.521	1.521	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517		1.521	1.521	1.521	
	1.521	1.525	1.525	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.518	1.518	1.518		1.525	1.524	1.523	
	1.525	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.522	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527					

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.716	1.715	1.714	1.719	1.720	1.719	1.719	1.720	1.723	3.604	1.723	1.723	1.715	1.723	1.719	1.719
2.401	1.723	1.719	1.719	1.725	1.724	1.723	1.723	1.723	1.724	3.807	1.724	1.724	1.723	1.724	1.725	1.723
2.403	1.724	1.721	1.721	2.401	1.725	1.731	1.724	1.725	1.725		1.725	1.725	1.724	1.725	2.401	1.724
3.602	1.725	1.723	2.401	2.408	1.731	2.401	1.725	1.726	1.726		1.726	1.726	1.725	1.726	3.603	1.726
3.604	1.728	1.724		2.409	2.206	2.402	1.726	1.731	1.731		1.727	1.731	1.726	1.731	3.604	1.731
	1.732	1.725		2.410	2.401	2.403	1.731	1.732	1.732		1.731	1.732	1.731	2.406		2.401
	1.735	1.731		3.604	2.402	2.408	1.732	1.733	1.733		1.732	1.733	1.732	3.604		2.402
	1.738	1.738			2.403	2.409	1.733	1.738	2.401		1.733	1.738	1.733	3.807		2.405
	2.206	2.401			2.407	2.410	1.736	2.401	2.402		1.734	2.401	1.734			2.406
	2.401	2.403			2.408	3.604	1.738	2.402	2.405		1.738	2.405	2.402			2.407
	3.602	2.406			2.409		2.401	2.403	2.406		2.401	2.406	2.405			2.408
	3.604	2.407			2.410		2.402	2.405	2.407		2.402	2.407	2.406			2.409
		2.408			3.603		2.403	2.406	2.408		2.405	2.408	2.407			2.410
		2.409			3.604		2.405	2.407	2.409		2.406	2.409	2.408			3.604
		2.410					2.406	2.408	2.410		2.407	2.410	2.409			3.807
		3.603					2.407	2.409	3.604		2.408	3.603	2.410			
		3.604					2.408	2.410	3.608		2.409	3.604	3.603			
		3.807					2.409	3.603	3.807		2.410	3.608	3.604			
							2.410	3.604			3.603	3.807	3.608			
							3.604				3.608	3.808	3.807			
							3.608				3.807		3.808			
							3.807									

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.704	1.707	1.703	1.703	1.705	1.705	1.703	1.703	1.707	1.707		1.703	1.707	1.707	1.707	1.705	1.707
1.706	1.708	1.704	1.704	1.709	1.708	1.707	1.707	1.709	1.708		1.706	1.708	1.708	1.708	1.709	1.708
	1.709	1.707			1.709		1.708	1.710	1.709		1.707	1.709	1.709	1.709		1.709
	1.711	1.708					1.709		1.710		1.708	1.710	1.710	1.710		1.710
		1.709					1.710				1.709					
											1.710					

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET K

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM CLEARCUTTING

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.712	1.801	1.901	2.201	2.301	3.601	3.804
	1.713	1.802	1.902	2.202	2.302	3.606	3.805
	1.717	1.803	1.903	2.205	2.306	3.607	3.806
	1.718		1.904		2.307		3.809
	1.729		1.905				3.812
	1.730		1.906				3.813
							3.814
							3.817
							3.818

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101	1.701	3.811
1.102	1.702	
1.103		
1.104		
1.105		
1.106		
1.107		
1.108		
1.109		
1.110		
1.111		
1.112		
1.113		

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.517	1.517	1.517	1.511	1.517	1.517	1.517	1.517	1.517	1.517		1.516	1.515	1.514	
	1.517	1.520	1.520	1.525	1.524	1.524	1.517	1.524	1.518	1.518	1.518	1.518	1.518		1.520	1.524	1.518	
	1.520	1.525	1.525	1.527	1.527	1.527	1.524	1.527	1.527	1.527	1.527	1.527	1.527		1.525	1.527	1.527	
	1.525	1.527	1.527				1.527								1.527			
	1.527																	

SORTING SET K CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.716	1.715	1.714	1.719	1.720	1.719	1.719	1.720	1.723	3.604	1.723	1.723	1.715	1.723	1.719	1.719
2.401	1.723	1.719	1.719	1.725	1.724	1.723	1.723	1.723	1.724		1.724	1.724	1.723	1.724	1.725	1.723
2.403	1.724	1.721	1.721	2.401	1.725	1.731	1.724	1.725	1.725		1.725	1.725	1.724	1.725	2.401	1.724
3.602	1.725	1.723	2.401	2.408	1.731	2.401	1.725	1.726	1.726		1.726	1.726	1.725	1.726	3.603	1.726
3.604	1.728	1.724		2.409	2.206	2.402	1.726	1.731	1.731		1.727	1.731	1.726	1.731	3.604	1.731
3.605	1.732	1.725		2.410	2.401	2.403	1.731	1.732	1.732		1.731	1.732	1.731	2.406	3.605	2.401
	1.735	1.731		3.604	2.402	2.408	1.732	1.733	1.733		1.732	1.733	1.732	3.604		2.402
	1.738	1.738		3.605	2.403	2.409	1.733	1.738	2.401		1.733	1.738	1.733	3.605		2.405
	2.206	2.401			2.407	2.410	1.736	2.401	2.402		1.734	2.401	1.734			2.406
	2.401	2.403			2.408	3.604	1.737	2.402	2.405		1.738	2.405	2.402			2.407
	3.602	2.406			2.409		1.738	2.403	2.406		2.401	2.406	2.405			2.408
	3.604	2.407			2.410		2.401	2.405	2.407		2.402	2.407	2.406			2.409
	3.605	2.408			3.603		2.402	2.406	2.408		2.405	2.408	2.407			2.410
		2.409			3.604		2.403	2.407	2.409		2.406	2.409	2.408			3.604
		2.410			3.605		2.405	2.408	2.410		2.407	2.410	2.409			3.605
		3.603					2.406	2.409	3.604		2.408	3.603	2.410			
		3.604					2.407	2.410			2.409	3.604	3.603			
		3.605					2.408	3.603			2.410	3.605	3.604			
							2.409	3.604			3.603	3.808	3.605			
							2.410	3.605					3.808			
							3.604									

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.704	1.707	1.703	1.703	1.705	1.705	1.703	1.703	1.707	1.707		1.703	1.707	1.707	1.707	1.705	1.707
1.706	1.708	1.704	1.704	1.709	1.708	1.707	1.707	1.709	1.708		1.706	1.708	1.708	1.708	1.709	1.708
	1.709	1.707			1.709		1.708	1.710	1.709		1.707	1.709	1.709	1.709		1.709
	1.711	1.708					1.709		1.710		1.708	1.710	1.710	1.710		1.710
		1.709					1.710				1.709					
											1.710					

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET L

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
PRECOMMERCIAL THINNING

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.712	1.801	1.901	2.201	2.301	3.601	3.804
	1.713	1.802	1.902	2.202	2.302	3.607	3.806
	1.717	1.803	1.903		2.303		3.809
	1.718		1.904		2.304		3.813
	1.729		1.905		2.305		3.814
	1.730		1.906		2.306		3.815
					2.307		3.816

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101	1.701	2.204
1.102	1.702	
1.103		
1.104		
1.105		
1.107		
1.109		
1.110		
1.111		
1.112		
1.113		

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.506	1.506	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507		1.516	1.515	1.514	
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.521	1.521	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517		1.521	1.521	1.521	
	1.521	1.525	1.525	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.518	1.518	1.518		1.525	1.524	1.523	
	1.525	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.522	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527					

SORTING SET L CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.716	1.715	1.714	1.719	1.720	1.719	1.719	1.720	1.723	3.807	1.723	1.723	1.715	1.723	1.719	1.719
	1.723	1.719	1.719	1.725	1.724	1.723	1.723	1.723	1.724		1.724	1.724	1.723	1.724	1.725	1.723
	1.724	1.721	1.721	2.408	1.725	1.731	1.724	1.725	1.725		1.725	1.725	1.724	1.725		1.724
	1.725	1.723			1.731	2.408	1.725	1.731	1.731		1.727	1.731	1.725	1.731		1.731
	1.728	1.724			2.206		1.731	1.732	1.732		1.731	1.732	1.731	2.406		2.405
	1.732	1.725			2.407		1.732	1.733	1.733		1.732	1.733	1.732	3.807		2.406
	1.735	1.731			2.408		1.733	1.738	2.405		1.733	1.738	1.733			2.407
	1.738	1.738					1.736	2.405	2.406		1.734	2.405	1.734			2.408
	2.206	2.406					1.738	2.406	2.407		1.738	2.406	2.405			3.807
		2.407					2.405	2.407	2.408		2.405	2.407	2.406			
		2.408					2.406	2.408	3.608		2.406	2.408	2.407			
		3.807					2.407		3.807		2.407	3.608	2.408			
							2.408				2.408	3.807	3.608			
							3.608				3.608	3.808	3.807			
							3.807				3.807		3.808			

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.704	1.707	1.703	1.703	1.705	1.705	1.703	1.703	1.707	1.707		1.703	1.707	1.707	1.707	1.705	1.707
1.706	1.708	1.704	1.704	1.709	1.708	1.707	1.707	1.709	1.708		1.706	1.708	1.708	1.708	1.709	1.708
	1.709	1.707			1.709		1.708	1.710	1.709		1.707	1.709	1.709	1.709		1.709
	1.711	1.708					1.709		1.710		1.708	1.710	1.710	1.710		1.710
		1.709					1.710				1.709					
											1.710					

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET M

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
COMMERCIAL THINNING

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.712	1.801	1.901	2.201	2.301	3.501	3.804
	1.713	1.802	1.902	2.202	2.302	3.507	3.806
	1.717	1.803	1.903		2.303		3.809
	1.718		1.904		2.306		3.813
	1.723		1.905		2.307		3.815
	1.730		1.906				3.816

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101	1.701	2.204
1.102	1.702	
1.103		
1.104		
1.106		
1.107		
1.109		
1.110		
1.111		
1.112		
1.113		

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.506	1.506	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507		1.516	1.515	1.514	
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.521	1.521	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517		1.521	1.521	1.521	
	1.521	1.525	1.525	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.518	1.518	1.518		1.525	1.524	1.523	
	1.525	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.522	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527					

SORTING SET M CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

							PROVINCE NUMBER									
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.716	1.715	1.714	1.719	1.720	1.719	1.719	1.720	1.723	3.807	1.723	1.723	1.715	1.723	1.719	1.719
2.401	1.723	1.719	1.719	1.725	1.724	1.723	1.723	1.723	1.724		1.724	1.724	1.723	1.724	1.725	1.723
2.403	1.724	1.721	1.721	2.401	1.725	1.731	1.724	1.725	1.725		1.725	1.725	1.724	1.725	2.401	1.724
	1.725	1.723	2.401	2.408	1.731	2.401	1.725	1.731	1.731		1.727	1.731	1.725	1.731		1.731
	1.728	1.724			2.206	2.402	1.731	1.732	1.732		1.731	1.732	1.731	2.406		2.401
	1.732	1.725			2.401	2.403	1.732	1.733	1.733		1.732	1.733	1.732	3.807		2.402
	1.735	1.731			2.402	2.408	1.733	1.738	2.401		1.733	1.738	1.733			2.405
	1.738	1.738			2.403		1.736	2.401	2.402		1.734	2.401	1.734			2.406
	2.206	2.401			2.407		1.738	2.402	2.405		1.738	2.405	2.402			2.407
	2.401	2.403			2.408		2.401	2.403	2.406		2.401	2.406	2.405			2.408
		2.406					2.402	2.405	2.407		2.402	2.407	2.406			3.807
		2.407					2.403	2.405	2.408		2.405	2.408	2.407			
		2.408					2.405	2.407	3.608		2.406	3.608	2.408			
		3.807					2.406	2.408	3.807		2.407	3.807	3.608			
							2.407				2.408	3.808	3.807			
							2.408				3.608		3.808			
							3.608				3.807					
							3.807									

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

							PROVINCE NUMBER									
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.704	1.707	1.703	1.703	1.705	1.705	1.703	1.703	1.707	1.707		1.703	1.707	1.707	1.707	1.705	1.707
1.706	1.708	1.704	1.704	1.709	1.708	1.707	1.707	1.703	1.708		1.706	1.708	1.708	1.708	1.709	1.708
	1.709	1.707			1.709		1.708		1.709		1.707	1.709	1.709	1.709		1.709
	1.711	1.708					1.709				1.708					
		1.709									1.709					

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET N

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
TYPE CONVERSION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.712	1.801	1.901	2.201	2.301	3.601	3.804
	1.713	1.802	1.902	2.202	2.302	3.507	3.805
	1.717	1.803	1.904		2.303		3.806
	1.718		1.905		2.306		3.809
	1.729		1.906		2.307		3.812
	1.730						3.813
							3.814
							3.815
							3.816

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101	1.701	2.204
1.102	1.702	
1.103		
1.104		
1.105		
1.106		
1.107		
1.108		
1.109		
1.110		
1.111		
1.113		

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.506	1.506	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507		1.516	1.515	1.514	
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.521	1.521	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517		1.521	1.521	1.521	
	1.521	1.525	1.525	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.518	1.518	1.518		1.525	1.524	1.523	
	1.525	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.527	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527		1.527	1.527	1.527	1.527					

SORTING SET N CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.716	1.715	1.714	1.719	1.720	1.719	1.719	1.720	1.723	3.807	1.723	1.723	1.715	1.723	1.719	1.719
3.602	1.723	1.719	1.719	1.725	1.724	1.723	1.723	1.723	1.724		1.724	1.724	1.723	1.724	1.725	1.723
3.605	1.724	1.721	1.721	3.605	1.725	1.731	1.724	1.725	1.725		1.725	1.725	1.724	1.725	3.603	1.724
	1.725	1.723			1.731		1.725	1.731	1.731		1.727	1.731	1.725	1.731	3.605	1.731
	1.728	1.724			2.206		1.731	1.732	1.732		1.731	1.732	1.731	3.605		3.605
	1.732	1.725			3.603		1.732	1.733	1.733		1.732	1.733	1.732	3.807		3.807
	1.735	1.731			3.605		1.733	1.738	3.807		1.733	1.738	1.733			
	1.738	1.738					1.736	3.603			1.734	3.603	1.734			
	2.206	3.603					1.738	3.605			1.738	3.605	3.603			
	3.602	3.605					3.807				3.603	3.807	3.605			
	3.605	3.807									3.807	3.808	3.807			
													3.808			

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.704	1.707	1.703	1.703	1.705	1.705	1.703	1.703	1.707	1.707		1.703	1.707	1.707	1.707	1.705	1.707
1.706	1.708	1.704	1.704	1.709	1.708	1.707	1.707	1.709	1.708		1.706	1.708	1.708	1.708	1.709	1.708
	1.709	1.707			1.709		1.708	1.710	1.709		1.707	1.709	1.709	1.709		1.709
	1.711	1.708					1.709		1.710		1.708	1.710	1.710	1.710		1.710
		1.709					1.710				1.709					
											1.710					

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET 0

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM NATURAL RESIDUE TREATMENT

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	2.306	3.501	3.810
	2.308	3.606	
	2.309		

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101	1.701	2.204
1.102	1.702	
1.103		
1.104		
1.105		
1.107		
1.109		
1.110		
1.111		
1.113		

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.506	1.506	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507	1.526	1.516	1.515	1.514	1.526
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.521	1.521	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517		1.521	1.521	1.521	
	1.521	1.525	1.525	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.518	1.518	1.518		1.525	1.524	1.523	
	1.525	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.522	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527					

SORTING SET O CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
3.602	3.602	2.406			3.603		2.310	2.405	2.310	2.310	2.310	2.310	2.310	2.310	3.603	2.310
		3.603					2.405	2.406	2.405		2.405	2.405	2.405	2.406		2.405
							2.406	3.603	2.406		2.406	2.406	2.406			2.406
											3.603	3.603	3.603			

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.704	1.707	1.703	1.703	1.705	1.705	1.703	1.703	1.707	1.707		1.703	1.707	1.707	1.707	1.705	1.707
1.706	1.708	1.704	1.704	1.709	1.708	1.707	1.707	1.709	1.708		1.706	1.708	1.708	1.708	1.709	1.708
	1.709	1.707			1.709		1.708		1.709		1.707	1.709	1.709	1.709		1.709
	1.711	1.708					1.709				1.708					
		1.709									1.709					

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET P

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
DYING AND DAMAGED VEGETATION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	2.306	3.501

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101	1.701	2.204
1.102	1.702	
1.103		
1.104		
1.105		
1.106		
1.107		
1.109		
1.110		
1.111		
1.113		

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.506	1.506	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507	1.526	1.516	1.515	1.514	1.526
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.521	1.521	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517		1.521	1.521	1.521	
	1.521	1.525	1.525	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.518	1.518	1.518		1.525	1.524	1.523	
	1.525	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.522	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527					

SORTING SET P CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
2.401	2.401	2.401	2.401	2.401	2.401	2.401	2.401	2.401	2.401		2.401	2.401	2.402		2.401	2.401
2.411	2.411	2.409	2.411	2.409	2.402	2.402	2.402	2.402	2.402		2.402	2.404	2.404		2.411	2.402
3.602	3.602	2.410		2.410	2.404	2.409	2.409	2.404	2.409		2.409	2.409	2.409		3.603	2.409
		2.411		2.411	2.409	2.410	2.410	2.409	2.410		2.410	2.410	2.410			2.410
		3.603			2.410	2.411	2.411	2.410	2.411		2.411	2.411	3.603			2.411
					2.411			2.411			3.603	3.603				
					3.603			3.603								

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.704	1.707	1.703	1.703	1.705	1.705	1.703	1.703	1.707	1.707		1.703	1.707	1.707	1.707	1.705	1.707
1.706	1.708	1.704	1.704	1.709	1.708	1.707	1.707	1.709	1.708		1.706	1.708	1.708	1.708	1.709	1.708
	1.709	1.707			1.709		1.708		1.709		1.707	1.709	1.709	1.709		1.709
	1.711	1.708					1.709				1.708					
		1.709									1.709					

TABLE SET I
GUIDELINES APPLYING TO PUBLIC LANDS
SORTING SET Q

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
RANGELAND TYPE CONVERSION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.502	1.712	1.801	1.901	2.201	2.301	3.804
	1.713	1.802	1.902		2.302	3.806
	1.717	1.803	1.904		2.306	3.813
	1.718		1.905		2.307	3.814
			1.906		2.309	3.815

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.101	1.701
1.102	1.702
1.103	
1.104	
1.105	
1.106	
1.107	
1.108	
1.109	
1.110	
1.111	
1.113	

TABLE 3. GUIDELINES APPLYING IN CLASSIFIED VISUAL MANAGEMENT ZONES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.501	1.511	1.517	1.517	1.506	1.506	1.507	1.510	1.510	1.504	1.504	1.505	1.506	1.507		1.516	1.515	1.514	
	1.517	1.520	1.520	1.508	1.509	1.510	1.511	1.512	1.508	1.508	1.509	1.509	1.509		1.520	1.519	1.518	
	1.520	1.521	1.521	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517	1.517		1.521	1.521	1.521	
	1.521	1.525	1.525	1.519	1.519	1.519	1.519	1.519	1.518	1.518	1.518	1.518	1.518		1.525	1.524	1.523	
	1.525	1.527	1.527	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521	1.521		1.527	1.527	1.527	
	1.527			1.525	1.524	1.524	1.524	1.524	1.522	1.523	1.523	1.523	1.523					
				1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527	1.527					

SORTING SET Q CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.722	1.716	1.715	1.714	1.719	1.720	1.719	1.719	1.720	1.723	3.807	1.723	1.723	1.715	1.723	1.719	1.719
	1.723	1.719	1.719	1.725	1.724	1.723	1.723	1.723	1.724		1.724	1.724	1.723	1.724	1.725	1.723
	1.724	1.721	1.721		1.725		1.724	1.725	1.725		1.725	1.725	1.724	1.725		1.724
	1.725	1.723					1.725	1.738	3.807		1.727	1.738	1.725	3.807		3.807
	1.728	1.724					1.738				1.738	3.807	3.807			
	1.738	1.725					3.807				3.807					
		1.738														
		3.807														

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.704	1.707	1.703	1.703	1.705	1.705	1.703	1.703	1.707	1.707		1.703	1.707	1.707	1.707	1.705	1.707
1.706	1.708	1.704	1.704	1.709	1.708	1.707	1.707	1.709	1.708		1.706	1.708	1.708	1.708	1.709	1.708
	1.709	1.707			1.709		1.708	1.710	1.709		1.707	1.709	1.709	1.709		1.709
	1.711	1.708					1.709		1.710		1.708	1.710	1.710	1.710		1.710
		1.709					1.710				1.709					
											1.710					

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 01
OLYMPIC

SUBPROVINCE NO.

	01	02	03	04	05
SPECIES ASSOCIATION 1	2.401	1.706	1.706	1.722	2.401
	2.403	1.722	1.722	2.401	2.403
	2.411	2.401	2.401	2.403	2.411
		2.403	2.403	2.411	
		2.411	2.411	3.602	
		3.602	3.602	3.604	
		3.604	3.604	3.605	
		3.605	3.605		
SPECIES ASSOCIATION 5	2.401	1.704	2.401	2.401	1.704
	2.403	1.722	2.403	2.403	1.722
	2.411	2.401	2.411	2.411	2.401
	3.602	2.403			2.403
	3.604	2.411			2.411
	3.605				3.602
					3.604
					3.605

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 02
COAST RANGES

SUBPROVINCE NO.

	01	02	03	04	05	06	07
SPECIES ASSOCIATION 1	1.709	2.401	1.709	2.206	1.708	1.707	1.711
	1.725	2.411	1.725	2.401	1.724	1.708	1.716
	1.732	3.602	1.732	2.411	2.401	1.723	1.728
	2.401	3.604	2.206	3.602	2.411	1.724	1.735
	2.411	3.605	2.401	3.604	3.602	2.401	1.738
	3.602		2.411	3.605	3.604	2.411	2.401
	3.604		3.602		3.605	3.602	2.411
	3.605		3.604			3.604	3.602
			3.605			3.605	3.604
							3.605

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 03
SISKIYOU

SUBPROVINCE NO.

	01	02	03	04	05	06
SPECIES ASSOCIATION 2	2.401	1.707	2.401	1.703	1.703	1.703
	2.403	1.723	2.403	1.707	1.709	1.719
	2.407	2.401	2.407	1.708	1.719	2.401
	2.408	2.403	2.408	1.709	1.725	2.403
	2.409	2.407	2.409	1.719	2.401	2.407
	2.410	2.408	2.410	1.723	2.403	2.408
	2.411	2.409	2.411	1.724	2.407	2.409
	3.807	2.410	3.807	1.725	2.408	2.410
		2.411		1.731	2.409	2.411
		3.603		2.401	2.410	3.604
		3.604		2.403	2.411	3.605
		3.605		2.407	3.604	3.807
		3.807		2.408	3.605	
				2.409	3.807	
				2.410		
				2.411		
				3.604		
				3.605		
				3.807		
SPECIES ASSOCIATION 4	1.703	2.401	1.704	2.401	2.401	2.401
	1.704	2.403	1.721	2.403	2.403	2.403
	1.709	2.407	1.731	2.407	2.407	2.407
	1.715	2.408	1.738	2.408	2.408	2.408
	1.719	2.409	2.401	2.409	2.409	2.409
	1.721	2.410	2.403	2.410	2.410	2.410
	1.725	2.411	2.407	2.411	2.411	2.411
	1.738	3.807	2.408	3.807	3.807	3.807
	2.401		2.409			
	2.403		2.410			
	2.407		2.411			
	2.408		3.603			
	2.409		3.604			
	2.410		3.605			
	2.411		3.807			
	3.603					
	3.604					
	3.605					
	3.807					

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 04
PUGET SOUND BASIN

SUBPROVINCE NO.

	01	02	03	04
SPECIES ASSOCIATION 1	2.401	1.703	1.719	2.401
	2.411	1.704	2.401	2.411
		1.714	2.411	
		1.719		
		1.721		
		2.401		
		2.411		

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 05
WILLAMETTE BASIN

SUBPROVINCE NO.

	01	02	03	04
SPECIES ASSOCIATION 3	2.401	2.401	1.705	1.705
	2.408	2.408	1.709	1.709
	2.409	2.409	1.719	1.719
	2.410	2.410	1.725	1.725
	2.411	2.411	2.401	2.401
	3.604	3.604	2.408	2.408
	3.605	3.605	2.409	2.409
			2.410	2.410
			2.411	2.411
			3.604	3.604
			3.605	3.605

FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 06
WESTERN CASCADES

SUBPROVINCE NO.

	01	02	03	04	05	06	07
SPECIES ASSOCIATION 1	1.708 1.724 2.401 2.403 2.411 3.604 3.605	1.703 1.724 2.401 2.403 2.411 3.604 3.605	1.705 1.720 2.401 2.403 2.411 3.604 3.605	1.708 1.724 2.401 2.403 2.411 3.604 3.605	1.708 1.724 2.401 2.403 2.411 3.604 3.605	1.705 1.708 1.720 1.724 2.401 2.403 2.411 3.604 3.605	2.401 2.403 2.411 3.604 3.605
SPECIES ASSOCIATION 2	2.401 2.403 2.404 2.407 2.408 2.409 2.410 2.411	2.401 2.403 2.404 2.407 2.408 2.409 2.410 2.411	2.401 2.403 2.404 2.407 2.408 2.409 2.410 2.411	1.708 1.709 1.724 1.725 2.206 2.401 2.403 2.404 2.407 2.408 2.409 2.410 2.411 3.603 3.604 3.605	1.708 1.724 2.401 2.403 2.404 2.407 2.408 2.409 2.410 2.411 3.604 3.605	1.708 1.724 2.206 2.401 2.413 2.404 2.407 2.408 2.409 2.410 2.411 3.604 3.605	2.401 2.403 2.404 2.407 2.408 2.409 2.410 2.411
SPECIES ASSOCIATION 3	2.401 2.403 2.408 2.409 2.410 2.411	2.401 2.403 2.408 2.409 2.410 2.411	1.731 2.401 2.403 2.408 2.409 2.410 2.411	2.401 2.403 2.408 2.409 2.410 2.411	2.401 2.403 2.408 2.409 2.410 2.411	2.401 2.403 2.408 2.409 2.410 2.411	2.401 2.403 2.408 2.409 2.410 2.411
SPECIES ASSOCIATION 5	2.401 2.402 2.403 2.408 2.409 2.410 2.411	2.401 2.402 2.403 2.408 2.409 2.410 2.411 3.604 3.605	2.401 2.402 2.403 2.408 2.409 2.410 2.411	2.401 2.402 2.403 2.408 2.409 2.410 2.411	2.401 2.402 2.403 2.408 2.409 2.410 2.411	2.401 2.402 2.403 2.408 2.409 2.410 2.411	2.401 2.402 2.403 2.408 2.409 2.410 2.411

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 07
NORTHWESTERN CASCADES

SUBPROVINCE NO.

	01	02	03	04	05	06	07
SPECIES ASSOCIATION 1	1.703 1.719 1.723 1.731 2.401 2.403 2.411	2.401 2.403 2.411	1.703 1.719 1.723 1.731 2.401 2.403 2.411	2.401 2.403 2.411	2.401 2.403 2.411	2.401 2.403 2.411	2.401 2.403 2.411
SPECIES ASSOCIATION 5	2.401 2.402 2.403 2.408 2.409 2.410 2.411	1.707 1.723 1.731 2.401 2.402 2.403 2.408 2.409 2.410 2.411 3.604	2.401 2.402 2.403 2.408 2.409 2.410 2.411	1.707 1.723 1.731 2.401 2.402 2.403 2.408 2.409 2.410 2.411 3.604	2.401 2.402 2.403 2.408 2.409 2.410 2.411	2.401 2.402 2.403 2.408 2.409 2.410 2.411	2.401 2.402 2.403 2.408 2.409 2.410 2.411

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 08
NORTHEASTERN CASCADES

SUBPROVINCE NO.

	01	02	03	04	05	06	07	08
SPECIES ASSOCIATION 5	2.401	1.707	2.401	1.707	2.401	2.401	2.401	2.401
	2.402	1.709	2.402	1.709	2.402	2.402	2.402	2.402
	2.403	1.710	2.403	1.710	2.403	2.403	2.403	2.403
	2.408	1.723	2.408	1.723	2.408	2.408	2.408	2.408
	2.409	1.725	2.409	1.725	2.409	2.409	2.409	2.409
	2.410	1.726	2.410	1.726	2.410	2.410	2.410	2.410
	2.411	1.731	2.411	1.731	2.411	2.411	2.411	2.411
		1.732		1.732				
		1.733		1.733				
		1.736		1.736				
		2.401		2.401				
		2.402		2.402				
		2.403		2.403				
		2.408		2.408				
		2.409		2.409				
		2.410		2.410				
		2.411		2.411				
		3.604		3.604				
SPECIES ASSOCIATION 6	2.310	2.310	1.707	2.310	2.310	2.310	2.310	2.310
	2.401	2.401	1.708	2.401	2.401	2.401	2.401	2.401
	2.402	2.402	1.709	2.402	2.402	2.402	2.402	2.402
	2.403	2.403	1.710	2.403	2.403	2.403	2.403	2.403
	2.405	2.405	1.723	2.405	2.405	2.405	2.405	2.405
	2.406	2.406	1.724	2.406	2.406	2.406	2.406	2.406
	2.407	2.407	1.725	2.407	2.407	2.407	2.407	2.407
	2.408	2.408	1.726	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	1.731	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	1.732	2.410	2.410	2.410	2.410	2.410
	2.411	2.411	1.733	2.411	2.411	2.411	2.411	2.411
	3.608	3.608	1.738	3.608	3.608	3.608	3.608	3.608
	3.807	3.807	2.310	3.807	3.807	3.807	3.807	3.807
			2.401					
			2.402					
			2.403					
			2.405					
			2.406					
			2.407					
			2.408					
			2.409					
			2.410					
			2.411					
			3.608					
			3.807					

(CONTINUED)

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 09
RECENT (HIGH) CASCADES

SUBPROVINCE NO.

	01	02	03	04	05
SPECIES ASSOCIATION 1	2.401	2.401	2.401	2.401	2.401
	2.403	2.403	2.403	2.403	2.403
	2.411	2.411	2.411	2.411	2.411
SPECIES ASSOCIATION 2	2.401	2.401	2.401	1.707	2.401
	2.403	2.403	2.403	1.709	2.403
	2.404	2.404	2.404	1.723	2.404
	2.407	2.407	2.407	1.725	2.407
	2.408	2.408	2.408	1.731	2.408
	2.409	2.409	2.409	1.732	2.409
	2.410	2.410	2.410	2.401	2.410
	2.411	2.411	2.411	2.403	2.411
				2.404	
				2.407	
				2.408	
				2.409	
				2.410	
				2.411	
				3.604	
				3.605	
SPECIES ASSOCIATION 3	2.401	1.707	1.707	1.707	1.707
	2.402	1.709	1.709	1.709	1.709
	2.408	1.710	1.710	1.710	1.710
	2.409	1.723	1.723	1.723	1.723
	2.410	1.725	1.725	1.725	1.725
	2.411	1.726	1.726	1.726	1.726
	3.604	1.731	1.731	1.731	1.731
	3.605	1.732	1.732	1.732	1.732
		1.733	1.733	1.733	1.733
		2.401	2.401	2.401	2.401
		2.402	2.402	2.402	2.402
		2.408	2.408	2.404	2.408
		2.409	2.409	2.408	2.409
		2.410	2.410	2.409	2.410
		2.411	2.411	2.410	2.411
		3.604	3.604	2.411	3.604
		3.605	3.605	3.604	3.605
				3.605	

SPECIES ASSOCIATION 7							
2.310	2.310	2.310	2.310	1.709	1.707	1.703	2.310
2.401	2.401	2.401	2.401	1.710	1.708	1.709	2.401
2.402	2.402	2.402	2.402	1.725	1.709	1.719	2.402
2.403	2.403	2.403	2.403	1.726	1.723	1.732	2.403
2.405	2.405	2.405	2.405	1.732	1.724	2.310	2.405
2.406	2.406	2.406	2.406	1.733	1.725	2.401	2.406
2.407	2.407	2.407	2.407	2.310	1.731	2.402	2.407
2.408	2.408	2.408	2.408	2.401	1.732	2.403	2.408
2.409	2.409	2.409	2.409	2.402	1.737	2.405	2.409
2.410	2.410	2.410	2.410	2.403	1.738	2.406	2.410
2.411	2.411	2.411	2.411	2.405	2.310	2.407	2.411
3.608	3.608	3.608	3.608	2.406	2.401	2.408	3.608
3.807	3.807	3.807	3.807	2.407	2.402	2.409	3.807
				2.408	2.403	2.410	
				2.409	2.405	2.411	
				2.410	2.406	3.608	
				2.411	2.407	3.807	
				3.608	2.408		
				3.807	2.409		
					2.410		
					2.411		
					3.608		
					3.807		

SPECIES ASSOCIATION 8							
2.310	2.310	2.310	2.310	2.310	1.709	2.310	2.310
2.401	2.401	2.401	2.401	2.401	1.724	2.401	2.401
2.402	2.402	2.402	2.402	2.402	1.725	2.402	2.402
2.403	2.403	2.403	2.403	2.403	2.310	2.403	2.403
2.405	2.405	2.405	2.405	2.405	2.401	2.405	2.405
2.406	2.406	2.406	2.406	2.406	2.402	2.406	2.406
2.407	2.407	2.407	2.407	2.407	2.403	2.407	2.407
2.408	2.408	2.408	2.408	2.408	2.405	2.408	2.408
2.409	2.409	2.409	2.409	2.409	2.406	2.409	2.409
2.410	2.410	2.410	2.410	2.410	2.407	2.410	2.410
2.411	2.411	2.411	2.411	2.411	2.408	2.411	2.411
3.608	3.608	3.608	3.608	3.608	2.409	3.608	3.608
3.807	3.807	3.807	3.807	3.807	2.410	3.807	3.807
					2.411		
					3.608		
					3.807		

SPECIES ASSOCIATION 9							
2.310	2.310	2.310	2.310	2.310	2.310	2.310	2.310
2.406	2.406	2.406	2.406	2.406	2.406	2.406	2.406
2.407	2.407	2.407	2.407	2.407	2.407	2.407	2.407
2.408	2.408	2.408	2.408	2.408	2.408	2.408	2.408
2.409	2.409	2.409	2.409	2.409	2.409	2.409	2.409
2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410
3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807

SPECIES ASSOCIATION 6				
2.401	1.707	2.401	2.401	1.707
2.402	1.709	2.402	2.402	1.709
2.405	1.710	2.405	2.405	1.710
2.406	1.723	2.406	2.406	1.723
2.407	1.725	2.407	2.407	1.725
2.408	1.726	2.408	2.408	1.726
2.409	1.731	2.409	2.409	1.731
2.410	1.732	2.410	2.410	1.732
2.411	1.733	2.411	2.411	1.733
3.603	2.401	3.603	3.603	2.401
	2.402			2.402
	2.404			2.404
	2.405			2.405
	2.406			2.406
	2.407			2.407
	2.408			2.408
	2.409			2.409
	2.410			2.410
	2.411			2.411
	3.603			3.603

SPECIES ASSOCIATION 7				
2.401	1.707	2.401	2.401	2.401
2.402	1.709	2.402	2.402	2.402
2.405	1.710	2.405	2.405	2.405
2.406	1.723	2.406	2.406	2.406
2.407	1.725	2.407	2.407	2.407
2.408	1.726	2.408	2.408	2.408
2.409	1.731	2.409	2.409	2.409
2.410	1.732	2.410	2.410	2.410
2.411	1.733	2.411	2.411	2.411
3.603	2.401	3.603	3.603	3.603
3.604	2.402	3.604	3.604	3.604
	2.405			
	2.406			
	2.407			
	2.408			
	2.409			
	2.410			
	2.411			
	3.603			
	3.604			

SPECIES ASSOCIATION 8				
2.401	1.710	2.401	1.710	2.401
2.402	1.720	2.402	1.720	2.402
2.405	1.726	2.405	1.726	2.405
2.406	1.733	2.406	1.733	2.406
2.407	1.738	2.407	1.738	2.407
2.408	2.401	2.408	2.401	2.408
2.409	2.402	2.409	2.402	2.409
2.410	2.405	2.410	2.405	2.410
2.411	2.406	2.411	2.406	2.411
3.603	2.407	3.603	2.407	3.603
	2.408		2.408	
	2.409		2.409	
	2.410		2.410	
	2.411		2.411	
	3.603		3.603	

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 10
OKANOGAN HIGHLANDS

SUBPROVINCE NO.

	01	02	03	04	05	06	07
SPECIES ASSOCIATION 5	2.401	2.401	2.401	2.401	2.401	2.401	1.707
	2.402	2.402	2.402	2.402	2.402	2.402	1.709
	2.408	2.408	2.408	2.408	2.408	2.408	1.723
	2.409	2.409	2.409	2.409	2.409	2.409	1.725
	2.410	2.410	2.410	2.410	2.410	2.410	1.731
	2.411	2.411	2.411	2.411	2.411	2.411	1.732
					3.604		2.401
							2.402
							2.408
							2.409
							2.410
							2.411
SPECIES ASSOCIATION 6	2.310	2.310	2.310	2.310	2.310	2.310	2.310
	2.401	2.401	2.401	2.401	2.401	2.401	2.401
	2.405	2.405	2.405	2.405	2.405	2.405	2.405
	2.406	2.406	2.406	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.410	2.410	2.410	2.410
	2.411	2.411	2.411	2.411	2.411	2.411	2.411
	3.807	3.807	3.807	3.807	3.807	3.807	3.807

(CONTINUED)

PROVINCE NO. 10
(CONTINUED)

SPECIES ASSOCIATION 7	1.707	1.707	1.707	1.707	2.310	2.310	2.310
	1.708	1.708	1.708	1.708	2.401	2.401	2.401
	1.709	1.709	1.709	1.709	2.402	2.402	2.402
	1.710	1.710	1.710	1.710	2.405	2.405	2.405
	1.723	1.723	1.723	1.723	2.406	2.406	2.406
	1.724	1.724	1.724	1.724	2.407	2.407	2.407
	1.725	1.725	1.725	1.725	2.408	2.408	2.408
	1.726	1.726	1.726	1.726	2.409	2.409	2.409
	1.731	1.731	1.731	1.731	2.410	2.410	2.410
	1.732	1.732	1.732	1.732	2.411	2.411	2.411
	1.733	1.733	1.733	1.733	3.807	3.608	3.807
	2.310	2.310	2.310	2.310		3.807	
	2.401	2.401	2.401	2.401			
	2.402	2.402	2.402	2.402			
	2.405	2.405	2.405	2.405			
	2.406	2.406	2.406	2.406			
	2.407	2.407	2.407	2.407			
	2.408	2.408	2.408	2.408			
	2.409	2.409	2.409	2.409			
	2.410	2.410	2.410	2.410			
	2.411	2.411	2.411	2.411			
	3.608	3.608	3.608	3.608			
	3.807	3.807	3.807	3.807			
SPECIES ASSOCIATION 8	2.310	2.310	2.310	2.310	2.310	2.310	2.310
	2.401	2.401	2.401	2.401	2.401	2.401	2.401
	2.405	2.405	2.405	2.405	2.405	2.405	2.405
	2.406	2.406	2.406	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.410	2.410	2.410	2.410
	2.411	2.411	2.411	2.411	2.411	2.411	2.411
	3.807	3.807	3.807	3.807	3.807	3.807	3.807
SPECIES ASSOCIATION 9	2.310	2.310	2.310	2.310	2.310	2.310	2.310
	2.406	2.406	2.406	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.410	2.410	2.410	2.410
	3.807	3.807	3.807	3.807	3.807	3.807	3.807

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 11
COLUMBIA BASIN

SUBPROVINCE NO.

	ANY
ANY SPECIES	2.310 3.807

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 12
BLUE MOUNTAINS

SUBPROVINCE NO.

	01	02	03	04	05	06	07	08	09	10	11
SPECIES ASSOCIATION 5	2.401	2.401	2.401	1.707	1.703	2.401	2.401	2.401	2.401	2.401	2.401
	2.402	2.402	2.402	1.708	1.707	2.402	2.402	2.402	2.402	2.402	2.402
	2.408	2.408	2.408	1.709	1.708	2.408	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	1.711	1.709	2.409	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	1.723	1.710	2.410	2.410	2.410	2.410	2.410	2.410
	2.411	2.411	2.411	1.724	1.723	2.411	2.411	2.411	2.411	2.411	2.411
		3.604		1.725	1.724						
				1.726	1.725						
				1.731	1.726						
				1.732	1.731						
				1.733	1.732						
				1.734	1.733						
				2.401	1.734						
				2.402	2.401						
				2.408	2.402						
				2.409	2.408						
				2.410	2.409						
				2.411	2.410						
				3.604	2.411						
SPECIES ASSOCIATION 6	2.310	2.310	2.310	1.703	2.310	1.703	2.310	2.310	2.310	2.310	2.310
	2.401	2.401	2.401	1.707	2.401	1.707	2.401	2.401	2.401	2.401	2.401
	2.405	2.405	2.405	1.709	2.405	1.709	2.405	2.405	2.405	2.405	2.405
	2.406	2.406	2.406	1.723	2.406	1.723	2.406	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	1.725	2.407	1.731	2.407	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	1.731	2.408	1.732	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	1.732	2.409	2.310	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.310	2.410	2.401	2.410	2.410	2.410	2.410	2.410
	2.411	2.411	2.411	2.401	2.411	2.405	2.411	2.411	2.411	2.411	2.411
	3.807	3.807	3.807	2.405	3.807	2.406	3.807	3.807	3.807	3.807	3.807
				2.406		2.407					
				2.407		2.408					
				2.408		2.409					
				2.409		2.410					
				2.410		2.411					
				2.411		3.807					
				3.807							

(CONTINUED)

PROVINCE NO. 12
(CONTINUED)

SPECIES ASSOCIATION 7	2.310	2.310	2.310	2.310	2.310	2.310	2.310	2.310	2.310	2.310	2.310
	2.401	2.401	2.401	2.401	2.401	2.401	2.401	2.401	2.401	2.401	2.401
	2.402	2.402	2.402	2.402	2.402	2.402	2.402	2.402	2.402	2.402	2.402
	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405
	2.406	2.406	2.406	2.406	2.406	2.406	2.406	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	2.407	2.407	2.407	2.407	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	2.408	2.408	2.408	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	2.409	2.409	2.409	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410
	2.411	2.411	2.411	2.411	2.411	2.411	2.411	2.411	2.411	2.411	2.411
	3.608	3.608	3.608	3.807	3.807	3.608	3.807	3.807	3.807	3.807	3.807
	3.807	3.807	3.807			3.807					
SPECIES ASSOCIATION 8	2.310	2.310	2.310	2.310	2.310	2.310	2.310	2.310	2.310	2.310	2.310
	2.401	2.401	2.401	2.401	2.401	2.401	2.401	2.401	2.401	2.401	2.401
	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405
	2.406	2.406	2.406	2.406	2.406	2.406	2.406	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	2.407	2.407	2.407	2.407	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	2.408	2.408	2.408	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	2.409	2.409	2.409	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.410
	2.411	2.411	2.411	2.411	2.411	2.411	2.411	2.411	2.411	2.411	2.411
	3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807
SPECIES ASSOCIATION 9	2.310	2.310	2.310	2.310	2.310	2.310	2.310	1.706	2.310	2.310	1.706
	2.406	2.406	2.406	2.406	2.406	2.406	2.406	1.727	2.406	2.406	1.727
	2.407	2.407	2.407	2.407	2.407	2.407	2.407	1.731	2.407	2.407	1.731
	2.408	2.408	2.408	2.408	2.408	2.408	2.408	1.732	2.408	2.408	1.732
	2.409	2.409	2.409	2.409	2.409	2.409	2.409	1.738	2.409	2.409	2.310
	2.410	2.410	2.410	2.410	2.410	2.410	2.410	2.310	2.410	2.410	2.406
	3.608	3.608	3.608	3.807	3.807	3.608	3.807	2.406	3.807	3.807	2.407
	3.807	3.807	3.807			3.807		2.407			2.408
								2.408			2.409
								2.409			2.410
								2.410			3.807
								3.807			

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 13
HARNEY BASIN

SUBPROVINCE NO.

	01	02	03	04	05	06
SPECIES ASSOCIATION 6	2.310	2.310	2.310	2.310	2.310	1.707
	2.401	2.401	2.401	2.401	2.401	1.708
	2.405	2.405	2.405	2.405	2.405	1.709
	2.406	2.406	2.406	2.406	2.406	1.710
	2.407	2.407	2.407	2.407	2.407	1.723
	2.408	2.408	2.408	2.408	2.408	1.724
	2.409	2.409	2.409	2.409	2.409	1.725
	2.410	2.410	2.410	2.410	2.410	1.726
	2.411	2.411	2.411	2.411	2.411	1.731
	3.603	3.603	3.603	3.603	3.603	1.732
	3.605	3.605	3.605	3.605	3.605	1.733
	3.807	3.807	3.608	3.807	3.807	1.738
			3.807			2.310
						2.401
						2.404
						2.405
						2.406
						2.407
						2.408
						2.409
						2.410
						2.411
						3.603
						3.605
						3.608
						3.808
SPECIES ASSOCIATION 7	2.310	2.310	2.310	2.310	2.310	2.310
	2.401	2.401	2.401	2.401	2.401	2.401
	2.405	2.405	2.405	2.405	2.405	2.405
	2.406	2.406	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.410	2.410	2.410
	2.411	2.411	2.411	2.411	2.411	2.411
	3.807	3.807	3.807	3.807	3.807	3.807

(CONTINUED)

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 14
UPPER BASIN AND RANGE

SUBPROVINCE NO.

	01	02	03	04	05	06	07
SPECIES ASSOCIATION 6	1.707	2.310	2.310	2.310	2.310	1.707	1.707
	1.708	2.402	2.402	2.402	2.402	1.708	1.708
	1.709	2.404	2.404	2.404	2.404	1.709	1.709
	1.710	2.405	2.405	2.405	2.405	1.710	1.710
	1.715	2.406	2.406	2.406	2.406	1.715	1.715
	1.723	2.407	2.407	2.407	2.407	1.723	1.723
	1.724	2.408	2.408	2.408	2.408	1.724	1.724
	1.725	2.409	2.409	2.409	2.409	1.725	1.725
	1.726	2.410	2.410	2.410	2.410	1.726	1.726
	1.731	3.608	3.608	3.608	3.608	1.731	1.731
	1.732	3.807	3.807	3.807	3.807	1.732	1.732
	1.733					1.733	1.733
	1.734					1.734	1.734
	2.310					2.310	2.310
	2.402					2.402	2.402
	2.404					2.404	2.404
	2.405					2.405	2.405
	2.406					2.406	2.406
	2.407					2.407	2.407
	2.408					2.408	2.408
	2.409					2.409	2.409
	2.410					2.410	2.410
	3.608					3.608	3.608
	3.807					3.807	3.808

(CONTINUED)

PROVINCE NO. 13
(CONTINUED)

SPECIES ASSOCIATION 8	2.310	2.310	2.310	2.310	2.310	2.310
	2.401	2.401	2.401	2.401	2.401	2.401
	2.405	2.405	2.405	2.405	2.405	2.405
	2.406	2.406	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.410	2.410	2.410
	2.411	2.411	2.411	2.411	2.411	2.411
	3.807	3.807	3.807	3.807	3.807	3.807
SPECIES ASSOCIATION 9	2.310	2.310	1.707	2.310	2.310	2.310
	2.406	2.406	1.708	2.406	2.406	2.406
	2.407	2.407	1.710	2.407	2.407	2.407
	2.408	2.408	1.723	2.408	2.408	2.408
	2.409	2.409	1.724	2.409	2.409	2.409
	2.410	2.410	1.726	2.410	2.410	2.410
	3.604	3.604	1.731	3.604	3.604	3.604
	3.605	3.605	1.732	3.605	3.605	3.605
	3.807	3.807	1.733	3.807	3.807	3.608
			1.738			3.807
			2.310			
			2.406			
			2.407			
			2.408			
			2.409			
			2.410			
			3.604			
			3.605			
			3.608			
			3.807			

PROVINCE NO. 14
(CONTINUED)

SPECIES ASSOCIATION 7	2.310	2.310	2.310	1.708	2.310	2.310	1.715
	2.402	2.402	2.402	1.709	2.402	2.402	2.310
	2.404	2.404	2.404	1.710	2.404	2.404	2.402
	2.405	2.405	2.405	1.724	2.405	2.405	2.404
	2.406	2.406	2.406	1.725	2.406	2.406	2.405
	2.407	2.407	2.407	1.726	2.407	2.407	2.406
	2.408	2.408	2.408	1.732	2.408	2.408	2.407
	2.409	2.409	2.409	1.733	2.409	2.409	2.408
	2.410	2.410	2.410	1.734	2.410	2.410	2.409
	3.603	3.603	3.603	2.310	3.603	3.603	2.410
	3.604	3.604	3.604	2.402	3.604	3.604	3.603
	3.605	3.605	3.605	2.404	3.605	3.605	3.604
	3.608	3.608	3.608	2.405	3.608	3.608	3.605
	3.807	3.807	3.807	2.406	3.807	3.807	3.608
				2.407			3.807
				2.408			
				2.409			
				2.410			
				3.603			
				3.604			
				3.605			
				3.608			
				3.807			
SPECIES ASSOCIATION 8	2.310	2.310	2.310	2.310	2.310	2.310	2.310
	2.405	2.405	2.405	2.405	2.405	2.405	2.405
	2.406	2.406	2.406	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.410	2.410	2.410	2.410
	3.807	3.807	3.807	3.807	3.807	3.807	3.807
SPECIES ASSOCIATION 9	2.310	2.310	2.310	2.310	2.310	2.310	2.310
	2.405	2.406	2.406	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.410	2.410	2.410	2.410
	3.807	3.807	3.807	3.807	3.807	3.807	3.807

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 15
BASIN AND RANGE

	SUBPROVINCE NO.
	05
SPECIES ASSOCIATION 9	1.707
	1.708
	1.709
	1.710
	1.723
	1.724
	1.725
	1.726
	1.731
	2.310
	2.406
	3.603
	3.604
	3.605
	3.807

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 16
COWLITZ RIVER BASIN

	SUBPROVINCE NO.			
	01	02	03	04
SPECIES ASSOCIATION 1	2.401	2.401	1.705	1.705
	2.411	2.411	1.709	1.709
	3.604	3.604	1.719	1.719
	3.605	3.605	1.725	1.725
			2.401	2.401
			2.411	2.411
			3.604	3.604
			3.605	3.605

TABLE SET IA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PUBLIC LAND

PROVINCE NO. 17
WALLOWAS

	SUBPROVINCE NO. 01	02	03	04
SPECIES ASSOCIATION 5	1.707	2.401	2.401	2.401
	1.708	2.402	2.402	2.402
	1.709	2.408	2.408	2.408
	1.723	2.409	2.409	2.409
	1.724	2.410	2.410	2.410
	1.726	2.411	2.411	2.411
	1.731	3.603	3.603	3.603
	2.401	3.604	3.604	3.604
	2.402	3.605	3.605	3.605
	2.408			
	2.409			
	2.410			
	2.411			
	3.603			
	3.604			
	3.605			
SPECIES ASSOCIATION 6	2.310	2.310	2.310	1.713
	2.401	2.401	2.401	2.310
	2.405	2.405	2.405	2.401
	2.406	2.406	2.406	2.405
	2.407	2.407	2.407	2.406
	2.408	2.408	2.408	2.407
	2.409	2.409	2.409	2.408
	2.410	2.410	2.410	2.409
	2.411	2.411	2.411	2.410
	3.807	3.807	3.807	2.411
				3.807

	SUBPROVINCE NO. 01	02	03	04
SPECIES ASSOCIATION 7	2.310	1.708	1.708	1.708
	2.401	1.709	1.709	1.709
	2.402	1.710	1.710	1.710
	2.405	1.724	1.724	1.724
	2.406	1.726	1.726	1.726
	2.407	2.310	2.310	1.731
	2.408	2.401	2.401	2.310
	2.409	2.402	2.402	2.401
	2.410	2.405	2.405	2.402
	2.411	2.406	2.406	2.405
	3.603	2.407	2.407	2.406
	3.604	2.408	2.408	2.407
	3.605	2.409	2.409	2.408
	3.807	2.410	2.410	2.409
		2.411	2.411	2.410
		3.603	3.603	2.411
		3.604	3.604	3.603
		3.605	3.605	3.604
		3.807	3.807	3.605
				3.807
SPECIES ASSOCIATION 8	2.310	2.310	2.310	2.310
	2.401	2.401	2.401	2.401
	2.405	2.405	2.405	2.405
	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.410
	2.411	2.411	2.411	2.411
	3.807	3.807	3.807	3.807
SPECIES ASSOCIATION 9	2.310	2.310	2.310	2.310
	2.406	2.406	2.406	2.406
	2.407	2.407	2.407	2.407
	2.408	2.408	2.408	2.408
	2.409	2.409	2.409	2.409
	2.410	2.410	2.410	2.410
	3.807	3.807	3.807	3.807

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET A

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
ROAD CONSTRUCTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.951	2.352	3.651
	1.952	2.353	3.655
	1.953	2.354	3.657
	1.954	2.355	
		2.356	
		2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.851	1.955	2.351
1.152		1.956	
1.153			
1.154			
1.155			
1.156			
1.157			
1.159			
1.160			
1.161			
1.162			
1.163			

TABLE SET II DOES NOT CONTAIN A TABLE 3.

SORTING SET A CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
2.451	1.773	1.773	2.451	2.451	1.770	1.773	1.773	1.770	1.773		1.773	1.773	1.773	1.773	2.451	1.773
	2.252	2.451		2.457	2.252	2.451	2.451	1.773	2.451		2.451	2.451	2.452			2.451
	2.451	2.457			2.451	2.452	2.452	2.451	2.452		2.452	2.457	2.457			2.452
					2.452	2.457	2.457	2.452	2.457		2.457					2.457
					2.457			2.457								

SORTING SET A DOES NOT CONTAIN ANY GUIDELINES IN TABLE 5.

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET B

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
TRAIL CONSTRUCTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.951	2.352
	1.952	2.353
	1.953	2.354
	1.954	2.355
		2.357

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.955	2.351
1.152	1.956	
1.153		
1.154		
1.155		
1.156		
1.157		
1.159		
1.160		
1.161		
1.162		
1.163		

TABLE SET II DOES NOT CONTAIN A TABLE 3.

SORTING SET B CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
2.451	1.773	1.773	2.451	2.451	1.770	1.773	1.773	1.770	1.773		1.773	1.773	1.773	1.773	2.451	1.773
	1.778	1.778			2.252	2.451	1.778	1.773	2.451		1.777	1.779	2.452			2.451
	2.252	2.451			2.451	2.452	2.451	1.778	2.452		1.778	2.451				2.452
	2.451				2.452		2.452	2.451			2.451					
								2.452			2.452					

SORTING SET B DOES NOT CONTAIN ANY GUIDELINES IN TABLE 5.

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET C

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
CAMPGROUND CONSTRUCTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.767	1.952	2.352	3.657
	1.768	1.953	2.353	
		1.954	2.354	
			2.355	
			2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151		1.955	2.351
1.152		1.956	
1.153			
1.154			
1.155			
1.156			
1.157			
1.159			
1.160			
1.161			
1.162			
1.163			

TABLE SET II DOES NOT CONTAIN A TABLE 3.

SORTING SET C CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

							PROVINCE NUMBER									
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
2.451	1.773	1.769	1.769	1.769	1.770	1.769	1.769	1.770	1.773		1.773	1.773	1.773	1.773	1.769	1.769
2.453	1.775	1.771	1.771	1.775	1.775	1.773	1.773	1.773	1.775		1.775	1.775	1.775	1.775	1.775	1.773
	2.252	1.773	2.451	2.451	2.252	2.451	1.775	1.775	2.451		1.777	2.451	2.452	2.456	2.451	2.451
	2.451	1.775		2.457	2.451	2.452	2.451	2.451	2.452		2.451	2.455	2.455			2.452
	2.453	2.451			2.452	2.453	2.452	2.452	2.455		2.452	2.456	2.456			2.455
		2.453			2.453	2.457	2.453	2.453	2.456		2.455	2.457	2.457			2.456
		2.456			2.457		2.455	2.455	2.457		2.456					2.457
		2.457					2.456	2.456			2.457					
							2.457	2.457								

SORTING SET C DOES NOT CONTAIN ANY GUIDELINES IN TABLE 5.

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET D

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
STRUCTURE CONSTRUCTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.952	2.352	3.655
	1.953	2.353	
	1.954	2.354	
		2.355	
		2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.955	2.351
1.152	1.956	
1.153		
1.154		
1.155		
1.156		
1.157		
1.158		
1.160		
1.161		
1.162		
1.163		

TABLE SET II DOES NOT CONTAIN A TABLE 3.

SORTING SET D CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
2.451	2.252	2.451	2.451	2.451	2.252	2.451	2.451	2.451	2.451		2.451	2.451	2.452	2.456	2.451	2.451
	2.451	2.456		2.457	2.451	2.452	2.452	2.452	2.452		2.452	2.455	2.455			2.452
		2.457			2.452	2.457	2.455	2.455	2.455		2.455	2.456	2.456			2.455
					2.457		2.456	2.456	2.456		2.456	2.457	2.457			2.456
							2.457	2.457	2.457		2.457					2.457

SORTING SET D DOES NOT CONTAIN ANY GUIDELINES IN TABLE 5.

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET E

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
SKI RUN CONSTRUCTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.767	1.952	2.352	3.655
		1.953	2.353	
		1.954	2.354	
			2.355	
			2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.955	2.351
1.152	1.956	
1.153		
1.154		
1.155		
1.156		
1.157		
1.159		
1.160		
1.161		
1.162		
1.163		

TABLE SET II DOES NOT CONTAIN A TABLE 3.

SORTING SET E CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
2.451	1.778	1.769	1.769	1.769	1.770	1.769	1.769	1.770	2.451		1.778	1.779	2.452		1.769	1.769
2.453	2.252	1.778	2.451	2.451	2.252	2.451	1.778	1.778	2.452		2.451	2.451	2.457		2.451	2.451
	2.451	2.451		2.457	2.451	2.452	2.451	2.451	2.457		2.452	2.457				2.452
	2.453	2.453			2.452	2.453	2.452	2.452			2.457					2.457
		2.457			2.453	2.457	2.453	2.453								
					2.457		2.457	2.457								

SORTING SET E DOES NOT CONTAIN ANY GUIDELINES IN TABLE 5.

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET F

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
UTILITY RIGHT-OF-WAY

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.763	1.951	2.352	3.651
	1.764	1.952	2.353	3.654
		1.953	2.354	3.655
		1.954	2.355	3.657
			2.357	3.659

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.851	1.955	2.351
1.152		1.956	
1.153			
1.154			
1.155			
1.156			
1.157			
1.159			
1.160			
1.161			
1.162			
1.163			

TABLE SET II DOES NOT CONTAIN A TABLE 3.

SORTING SET F CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
2.451	1.775	1.769	1.765	1.769	1.770	1.769	1.769	1.770	1.775	3.852	1.775	1.775	1.775	1.775	1.769	1.769
3.653	2.252	1.775	1.769	1.775	1.775	2.451	1.775	1.775	2.451		1.777	2.451	2.452	2.456	1.775	2.451
	2.451	2.451	2.451	2.451	2.252	2.452	2.451	2.451	2.452		2.451	2.455	2.455	3.653	2.451	2.452
	3.653	2.456		2.457	2.451	2.457	2.452	2.452	2.455		2.452	2.456	2.456	3.852	3.653	2.455
		2.457		3.653	2.452		2.455	2.455	2.456		2.455	2.457	2.457			2.456
		3.653			2.457		2.456	2.456	2.457		2.456	3.653	3.653			2.457
		3.852			3.653		2.457	2.457	3.852		2.457	3.852	3.852			3.653
							3.852	3.653			3.852	3.853	3.853			3.852

SORTING SET F DOES NOT CONTAIN ANY GUIDELINES IN TABLE 5.

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET G

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
INDIVIDUAL TREE SELECTION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.763	1.951	2.352	3.654
	1.764	1.952	2.353	3.655
	1.767	1.953	2.354	3.659
	1.768	1.954	2.355	
			2.356	
			2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.751	1.851	1.955	2.351
1.152	1.752		1.956	
1.153	1.753			
1.154				
1.156				
1.157				
1.159				
1.160				
1.161				
1.162				
1.163				

TABLE SET II DOES NOT CONTAIN A TABLE 3.

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.772	1.762	1.766	1.765	1.769	1.770	1.769	1.769	1.770	1.773	3.852	1.773	1.773	1.766	1.773	1.769	1.769
2.451	1.773	1.769	1.769	1.775	1.774	1.773	1.773	1.773	1.774		1.774	1.774	1.773	1.774	1.775	1.773
2.453	1.774	1.771	1.771	2.451	1.775	2.451	1.774	1.775	1.775		1.775	1.775	1.774	1.775	2.451	1.774
3.658	1.775	1.773	2.451	2.457	2.252	2.452	1.775	1.778	2.451		1.777	1.778	1.775	2.456		2.451
	1.778	1.774			2.451	2.453	1.778	2.451	2.452		1.778	2.451	2.452	3.852		2.452
	2.252	1.775			2.452	2.457	2.451	2.452	2.455		2.451	2.455	2.455			2.455
	2.451	1.778			2.453	3.658	2.452	2.453	2.456		2.452	2.456	2.456			2.456
	2.453	2.451			2.457		2.453	2.455	2.457		2.455	2.457	2.457			2.457
		2.453			3.658		2.455	2.456	3.658		2.456	3.852	3.852			3.852
		2.456					2.456	2.457	3.852		2.457	3.853	3.853			
		2.457					2.457	3.658			3.658					
		3.852					3.658				3.852					
							3.852									

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.755	1.758	1.754	1.754	1.756	1.756	1.754	1.754	1.758	1.758		1.754	1.758	1.758	1.758	1.756	1.758
1.757	1.759	1.755	1.755	1.760	1.759	1.758	1.758	1.760	1.759		1.757	1.759	1.759	1.759	1.760	1.759
	1.760	1.758			1.760		1.759		1.760		1.758	1.760	1.760	1.760		1.760
		1.759					1.760				1.759					
		1.760									1.760					

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET H

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM SHELTERWOOD CUTTING

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.763	1.951	2.352	3.651
	1.764	1.952	2.353	3.654
	1.767	1.953	2.354	3.655
	1.768	1.954	2.355	3.659
			2.356	
			2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.751	1.851	1.955	2.351
1.152	1.752		1.956	
1.153	1.753			
1.154				
1.156				
1.157				
1.159				
1.160				
1.161				
1.162				
1.163				

TABLE SET II DOES NOT CONTAIN A TABLE 3.

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

							PROVINCE NUMBER									
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.772	1.762	1.766	1.765	1.769	1.770	1.769	1.769	1.770	1.773	3.852	1.773	1.773	1.766	1.773	1.769	1.769
2.451	1.773	1.769	1.769	1.775	1.774	1.773	1.773	1.773	1.774		1.774	1.774	1.773	1.774	1.775	1.773
2.453	1.774	1.771	1.771	2.451	1.775	2.451	1.774	1.775	1.775		1.775	1.775	1.774	1.775	2.451	1.774
3.652	1.775	1.773	2.451	2.457	2.252	2.452	1.775	1.778	2.451		1.777	1.778	1.775	2.456	3.652	2.451
3.658	1.778	1.774		3.652	2.451	2.453	1.778	2.451	2.452		1.778	2.451	2.452	3.652		2.452
	2.252	1.775			2.452	2.457	2.451	2.452	2.455		2.451	2.455	2.455	3.852		2.455
	2.451	1.778			2.453	3.652	2.452	2.453	2.456		2.452	2.456	2.456			2.456
	2.453	2.451			2.457	3.658	2.453	2.455	2.457		2.455	2.457	2.457			2.457
	3.652	2.453			3.652		2.455	2.456	3.652		2.456	3.652	3.652			3.652
		2.456			3.658		2.456	2.457	3.658		2.457	3.852	3.852			3.852
		2.457					2.457	3.652	3.852		3.652	3.853	3.853			
		3.652					3.652	3.658			3.658					
		3.852					3.658				3.852					
							3.852									

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

							PROVINCE NUMBER									
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.755	1.758	1.754	1.754	1.756	1.756	1.754	1.754	1.758	1.758		1.754	1.758	1.758	1.758	1.756	1.758
1.757	1.759	1.755	1.755	1.760	1.759	1.758	1.758	1.760	1.759		1.757	1.759	1.759	1.759	1.760	1.759
	1.760	1.758			1.760		1.759		1.760		1.758	1.760	1.760	1.760		1.760
		1.759					1.760		3.656		1.759	3.656	3.656			
		1.760					3.656				1.760					
											3.656					

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET J

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
GROUP SELECTION CUTTING

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.763	1.951	2.251	2.352	3.651
	1.764	1.952		2.353	3.654
	1.767	1.953		2.354	3.655
	1.768	1.954		2.355	3.659
				2.356	
				2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.751	1.851	1.955	2.351
1.152	1.752		1.956	
1.153	1.753			
1.154				
1.156				
1.157				
1.159				
1.160				
1.161				
1.162				
1.163				

TABLE SET II DOES NOT CONTAIN A TABLE 3.

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.772	1.762	1.766	1.765	1.769	1.770	1.769	1.769	1.770	1.773	3.852	1.773	1.773	1.766	1.773	1.769	1.769
2.451	1.773	1.769	1.769	1.775	1.774	1.773	1.773	1.773	1.774		1.774	1.774	1.773	1.774	1.775	1.773
2.453	1.774	1.771	1.771	2.451	1.775	2.451	1.774	1.775	1.775		1.775	1.775	1.774	1.775	2.451	1.774
3.652	1.775	1.773	2.451	2.457	2.252	2.452	1.775	1.776	1.776		1.776	1.776	1.775	1.776	3.652	1.776
3.658	1.778	1.774		3.652	2.451	2.453	1.776	1.778	2.451		1.777	1.778	1.776	2.456		2.451
	2.252	1.775			2.452	2.457	1.778	2.451	2.452		1.778	2.451	2.452	3.652		2.452
	2.451	1.778			2.453	3.652	2.451	2.452	2.455		2.451	2.455	2.455	3.852		2.455
	2.453	2.451			2.457	3.658	2.452	2.453	2.456		2.452	2.455	2.456			2.456
	3.652	2.453			3.652		2.453	2.455	2.457		2.455	2.457	2.457			2.457
		2.456			3.658		2.455	2.456	3.652		2.456	3.652	3.652			3.652
		2.457					2.456	2.457	3.658		2.457	3.852	3.852			3.852
		3.652					2.457	3.652	3.852		3.652	3.853	3.853			
		3.852					3.652	3.658			3.658					
							3.658				3.852					
							3.852									

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.755	1.758	1.754	1.754	1.756	1.756	1.754	1.754	1.758	1.758		1.754	1.758	1.758	1.758	1.756	1.758
1.757	1.759	1.755	1.755	1.760	1.759	1.758	1.758	1.760	1.759		1.757	1.759	1.759	1.759	1.760	1.759
	1.760	1.758			1.760		1.759	1.761	1.760		1.758	1.760	1.760	1.760		1.760
		1.759					1.760		1.761		1.759	1.761	1.761	1.761		1.761
		1.760					1.761		3.656		1.760	3.656	3.656			
							3.656				1.761					
											3.656					

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET K

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM CLEARCUTTING

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.763	1.951	2.251	2.352	3.651
	1.764	1.952		2.353	3.654
	1.767	1.953		2.354	3.655
	1.768	1.954		2.355	3.659
				2.356	
				2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.751	1.851	1.955	2.351
1.152	1.752		1.956	
1.153	1.753			
1.154				
1.155				
1.156				
1.157				
1.158				
1.159				
1.160				
1.161				
1.162				
1.163				

TABLE SET II DOES NOT CONTAIN A TABLE 3.

SORTING SET K CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.772	1.762	1.766	1.765	1.769	1.770	1.769	1.769	1.770	1.773		1.773	1.773	1.766	1.773	1.769	1.769
2.451	1.773	1.769	1.769	1.775	1.774	1.773	1.773	1.773	1.774		1.774	1.774	1.773	1.774	1.775	1.773
2.453	1.774	1.771	1.771	2.451	1.775	2.451	1.774	1.775	1.775		1.775	1.775	1.774	1.775	2.451	1.774
3.653	1.775	1.773	2.451	2.457	2.252	2.452	1.775	1.776	1.776		1.776	1.775	1.775	1.776	3.653	1.776
3.658	1.778	1.774		3.653	2.451	2.453	1.776	1.778	2.451		1.777	1.778	1.776	3.653		2.451
	2.252	1.775			2.452	2.457	1.778	2.451	2.452		1.778	2.451	2.452			2.452
	2.451	1.778			2.453	3.658	2.451	2.452	2.455		2.451	2.455	2.455			2.455
	2.453	2.451			2.457		2.452	2.453	2.457		2.452	2.457	2.457			2.457
	3.653	2.453			3.653		2.453	2.455	3.658		2.455	3.653	3.653			3.653
		2.457			3.658		2.455	2.457			2.457	3.853	3.853			
		3.653					2.457	3.653			3.658					
							3.658	3.658								

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.755	1.758	1.754	1.754	1.756	1.756	1.754	1.754	1.758	1.758		1.754	1.758	1.758	1.758	1.756	1.758
1.757	1.759	1.755	1.755	1.760	1.759	1.758	1.758	1.760	1.759		1.757	1.759	1.759	1.759	1.760	1.759
	1.760	1.758			1.760		1.759	1.761	1.760		1.758	1.760	1.760	1.760		1.760
		1.759					1.760		1.761		1.759	1.761	1.761	1.761		1.761
		1.760					1.761				1.760					
											1.761					

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET L

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
PRECOMMERCIAL THINNING

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.763	1.951	2.352	3.654
	1.764	1.952	2.353	3.655
	1.767	1.953	2.354	3.657
	1.768	1.954	2.355	
			2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.751	1.851	1.955	2.351
1.152	1.752		1.956	
1.153	1.753			
1.154				
1.156				
1.157				
1.159				
1.160				
1.161				
1.162				
1.163				

TABLE SET II DOES NOT CONTAIN A TABLE 3.

SORTING SET L CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.772	1.762	1.766	1.765	1.769	1.770	1.769	1.769	1.770	1.773	3.852	1.773	1.773	1.766	1.773	1.769	1.769
3.658	1.773	1.769	1.769	1.775	1.774	1.773	1.773	1.773	1.774		1.774	1.774	1.773	1.774	1.775	1.773
	1.774	1.771	1.771		1.775	3.658	1.774	1.775	1.775		1.775	1.775	1.774	1.775		1.774
	1.775	1.773			2.252		1.775	1.778	2.455		1.777	1.778	1.775	2.456		2.455
	1.778	1.774			3.658		1.778	2.455	2.456		1.778	2.455	2.455	3.852		2.456
	2.252	1.775					2.455	2.456	3.658		2.455	2.456	2.456			3.852
		1.778					2.456	3.658	3.852		2.456	3.852	3.852			
		2.456					3.658				3.658	3.853	3.853			
		3.852					3.852				3.852					

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.755	1.758	1.754	1.754	1.756	1.756	1.754	1.754	1.758	1.758		1.754	1.758	1.758	1.758	1.756	1.758
1.757	1.759	1.755	1.755	1.760	1.759	1.758	1.758	1.760	1.759		1.757	1.759	1.759	1.759	1.760	1.759
	1.760	1.758			1.760		1.759	1.761	1.760		1.758	1.760	1.760	1.760		1.760
		1.759					1.760		1.761		1.759	1.761	1.761	1.761		1.761
		1.760					1.761		3.656		1.760	3.656	3.656			
							3.656				1.761					
											3.656					

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET M

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
COMMERCIAL THINNING

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.763	1.951	2.352	3.654
	1.764	1.952	2.353	3.655
	1.767	1.953	2.354	
	1.768	1.954	2.355	
			2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.751	1.851	1.955	2.351
1.152	1.752		1.956	
1.153	1.753			
1.154				
1.156				
1.157				
1.159				
1.160				
1.161				
1.162				
1.163				

TABLE SET II DOES NOT CONTAIN A TABLE 3.

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.772	1.762	1.766	1.765	1.769	1.770	1.769	1.769	1.770	1.773	3.852	1.773	1.773	1.766	1.773	1.769	1.769
2.451	1.773	1.769	1.769	1.775	1.774	1.773	1.773	1.773	1.774		1.774	1.774	1.773	1.774	1.775	1.773
2.453	1.774	1.771	1.771	2.451	1.775	2.451	1.774	1.775	1.775		1.775	1.775	1.774	1.775	2.451	1.774
3.658	1.775	1.773	2.451		2.252	2.452	1.775	1.778	2.451		1.777	1.778	1.775	2.456		2.451
	1.778	1.774			2.451	2.453	1.778	2.451	2.452		1.778	2.451	2.452	3.852		2.452
	2.252	1.775			2.452	3.658	2.451	2.452	2.455		2.451	2.455	2.455			2.455
	2.451	1.778			2.453		2.452	2.453	2.456		2.452	2.456	2.456			2.456
	2.453	2.451			3.658		2.453	2.455	3.658		2.455	3.852	3.852			3.852
		2.453					2.455	2.456	3.852		2.456	3.853	3.853			
		2.456					2.456	3.658			3.658					
		3.852					3.658				3.852					
							3.852									

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.755	1.758	1.754	1.754	1.756	1.756	1.754	1.754	1.758	1.758		1.754	1.758	1.758	1.758	1.756	1.758
1.757	1.759	1.755	1.755	1.760	1.759	1.758	1.758	1.760	1.759		1.757	1.759	1.759	1.759	1.760	1.759
	1.760	1.758			1.760		1.759		1.760		1.758	1.760	1.760	1.760		1.760
		1.759					1.760		3.656		1.759	3.655	3.656			
		1.760					3.656				1.760					
											3.656					

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET N

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
TYPE CONVERSION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.763	1.951	2.352	3.651
	1.764	1.952	2.353	3.654
	1.767	1.953	2.354	3.655
	1.768	1.954	2.355	3.657
			2.357	3.659

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.751	1.851	2.351
1.152	1.752		
1.153	1.753		
1.154			
1.155			
1.156			
1.157			
1.158			
1.159			
1.160			
1.161			
1.162			
1.163			

TABLE SET II DOES NOT CONTAIN A TABLE 3.

SORTING SET N CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.772	1.762	1.766	1.765	1.769	1.770	1.769	1.769	1.770	1.773	3.852	1.773	1.773	1.766	1.773	1.769	1.769
3.653	1.773	1.769	1.769	1.775	1.774	1.773	1.773	1.773	1.774		1.774	1.774	1.773	1.774	1.775	1.773
	1.774	1.771	1.771	3.653	1.775		1.774	1.775	1.775		1.775	1.775	1.774	1.775	3.653	1.774
	1.775	1.773			2.252		1.775	1.778	3.852		1.777	1.778	1.775	3.653		3.653
	1.778	1.774			3.653		1.778	3.653			1.778	3.653	3.653	3.852		3.852
	2.252	1.775					3.852				3.852	3.852	3.852			
	3.653	1.778										3.853	3.853			
		3.653														
		3.852														

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.755	1.758	1.754	1.754	1.756	1.756	1.754	1.754	1.758	1.758		1.754	1.758	1.758	1.758	1.756	1.758
1.757	1.759	1.755	1.755	1.760	1.759	1.758	1.758	1.760	1.759		1.757	1.759	1.759	1.759	1.760	1.759
	1.760	1.758			1.760		1.759	1.761	1.760		1.758	1.760	1.760	1.760		1.760
		1.759					1.760		1.761		1.759	1.761	1.761	1.761		1.761
		1.760					1.761				1.760					
											1.761					

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TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET 0

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
NATURAL RESIDUE TREATMENT

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	2.352	3.651
	2.353	
	2.354	
	2.355	
	2.357	

TABLE 2. GUIDELINES APPLICABLF IF RESIDUES WILL BE BURNED

1.151	2.351
1.152	
1.153	
1.154	
1.156	
1.157	
1.159	
1.160	
1.161	
1.162	
1.163	

TABLE SET II DOES NOT CONTAIN A TARLE 3.

SORTING SET 0 CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
		2.456					2.455	2.455	2.455		2.455	2.455	2.455	2.456		2.455
							2.456	2.456	2.456		2.456	2.456	2.456			2.456

SORTING SET 0 DOES NOT CONTAIN ANY GUIDELINES IN TABLE 5.

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET P

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
DYING AND DAMAGED VEGETATION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	2.352	3.651
	2.353	
	2.354	
	2.355	
	2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	2.351
1.152	
1.153	
1.154	
1.155	
1.156	
1.157	
1.159	
1.160	
1.161	
1.162	
1.163	

TABLE SET II DOES NOT CONTAIN A TABLE 3.

SORTING SET P CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
2.451	2.451	2.451	2.451	2.451	2.451	2.451	2.451	2.451	2.451		2.451	2.451	2.452		2.451	2.451
		2.457		2.457	2.452	2.452	2.452	2.452	2.452		2.452	2.454	2.454			2.452
					2.454	2.457	2.457	2.454	2.457		2.457	2.457	2.457			2.457
					2.457			2.457								

SORTING SET P DOES NOT CONTAIN ANY GUIDELINES IN TABLE 5.

TABLE SET II
GUIDELINES APPLYING TO PRIVATE LAND
SORTING SET Q

GUIDELINES FOR TREATMENT OF RESIDUES RESULTING FROM
RANGELAND TYPE CONVERSION

TABLE 1. GUIDELINES APPLICABLE THROUGHOUT THE PACIFIC NORTHWEST

1.551	1.763	1.951	2.352	3.655
	1.764	1.952	2.353	
	1.767	1.953	2.354	
		1.954	2.355	
			2.357	

TABLE 2. GUIDELINES APPLICABLE IF RESIDUES WILL BE BURNED

1.151	1.751	1.851	2.351
1.152	1.752		
1.153	1.753		
1.154			
1.155			
1.156			
1.157			
1.158			
1.159			
1.160			
1.161			
1.162			
1.163			

TABLE SET II DOES NOT CONTAIN A TABLE 3.

SORTING SET Q CONTINUED

TABLE 4. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.772	1.762	1.766	1.765	1.769	1.770	1.769	1.769	1.770	1.773	3.852	1.773	1.773	1.766	1.773	1.769	1.769
	1.773	1.769	1.769	1.775	1.774	1.773	1.773	1.773	1.774		1.774	1.774	1.773	1.774	1.775	1.773
	1.774	1.771	1.771		1.775		1.774	1.775	1.775		1.775	1.775	1.774	1.775		1.774
	1.775	1.773					1.775	1.778	3.852		1.777	1.778	1.775	3.852		3.852
	1.778	1.774					1.778				1.778	3.852	3.852			
		1.775					3.852				3.852					
		1.778														
		3.852														

TABLE 5. GUIDELINES APPLYING IN SPECIFIC GEOGRAPHIC AREAS WHEN RESIDUES WILL BE BURNED

PROVINCE NUMBER																
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
1.755	1.758	1.754	1.754	1.756	1.756	1.754	1.754	1.758	1.758		1.754	1.758	1.758	1.758	1.756	1.758
1.757	1.759	1.755	1.755	1.760	1.759	1.758	1.758	1.760	1.759		1.757	1.759	1.759	1.759	1.760	1.759
	1.760	1.758			1.760		1.759	1.761	1.760		1.758	1.760	1.760	1.760		1.760
		1.759					1.760		1.761		1.759	1.761	1.761	1.761		1.761
		1.760					1.761				1.760					
											1.761					

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 01
OLYMPIC

SUBPROVINCE NO.

	01	02	03	04	05
SPECIES ASSOCIATION 1	2.451 2.453	1.757 1.772 2.451 2.453 3.652 3.653	1.757 1.772 2.451 2.453 3.652 3.653	1.772 2.451 2.453 3.652 3.653	2.451 2.453
SPECIES ASSOCIATION 5	2.451 2.453 3.652 3.653 3.658	1.755 1.772 2.451 2.453	2.451 2.453	2.451 2.453	1.755 1.772 2.451 2.453 3.652 3.653 3.658

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 02
COAST RANGES

SUBPROVINCE NO.

	01	02	03	04	05	06	07
SPECIES ASSOCIATION 1	1.760 1.775 2.451 3.652 3.653	2.451 3.652 3.653	1.760 1.775 2.451 3.652 3.653	2.451 3.652 3.653	1.759 1.774 2.451 3.652 3.653	1.758 1.759 1.773 1.774 2.451 3.652 3.653	1.762 1.778 2.451 3.652 3.653

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 03
SISKIYOU

SUBPROVINCE NO.

	01	02	03	04	05	06
SPECIES ASSOCIATION 2	2.451 2.453 2.457 3.852	1.758 1.773 2.451 2.453 2.457 3.652 3.653 3.852	2.451 2.453 2.457 3.852	1.754 1.758 1.759 1.760 1.769 1.773 1.774 1.775 2.451 2.453 2.457 3.652 3.653 3.852	1.754 1.760 1.769 1.775 2.451 2.453 2.457 3.652 3.653 3.852	1.754 1.769 2.451 2.453 2.457 3.652 3.653 3.852
SPECIES ASSOCIATION 4	1.754 1.755 1.760 1.766 1.769 1.771 1.775 1.778 2.451 2.453 2.457 3.652 3.653 3.852	2.451 2.453 2.457 3.852	1.755 1.771 1.778 2.451 2.453 2.457 3.652 3.653 3.852	2.451 2.453 2.457 3.852	2.451 2.453 2.457 3.852	2.451 2.453 2.457 3.852

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 04
PUGET SOUND BASIN

SUBPROVINCE NO.

	01	02	03	04
SPECIES ASSOCIATION 1	2.451	1.754 1.755 1.765 1.769 1.771 2.451	1.769 2.451	2.451

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 05
WILLAMETTE BASIN

SUBPROVINCE NO.

	01	02	03	04
SPECIES ASSOCIATION 3	2.451 2.457 3.652 3.653	2.451 2.457 3.652 3.653	1.756 1.760 1.769 1.775 2.451 2.457 3.652 3.653	1.756 1.760 1.769 1.775 2.451 2.457 3.652 3.653

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 06
WESTERN CASCADES

SUBPROVINCE NO.

	01	02	03	04	05	06	07
SPECIES ASSOCIATION 1	1.759 1.774 2.451 2.453 3.652 3.653	1.759 1.774 2.451 2.453 3.652 3.653	1.756 1.770 2.451 2.453 3.652 3.653	1.759 1.774 2.451 2.453 3.652 3.653	1.759 1.774 2.451 2.453 3.652 3.653	1.756 1.759 1.770 1.774 2.451 2.453 3.652 3.653	2.451 2.453 3.652 3.653
SPECIES ASSOCIATION 2	2.451 2.453 2.454 2.457	2.451 2.453 2.454 2.457	2.451 2.453 2.454 2.457	1.759 1.760 1.774 1.775 2.451 2.453 2.454 2.457 3.652 3.653	1.759 1.774 2.451 2.453 2.454 2.457 3.652 3.653	1.759 1.774 2.451 2.453 2.454 2.457 3.652 3.653	2.451 2.453 2.454 2.457
SPECIES ASSOCIATION 3	2.451 2.453 2.457	2.451 2.453 2.457	2.451 2.453 2.457	2.451 2.453 2.457	2.451 2.453 2.457	2.451 2.453 2.457	2.451 2.453 2.457
SPECIES ASSOCIATION 5	2.451 2.452 2.453 2.457	2.451 2.452 2.453 2.457 3.652 3.653 3.658	2.451 2.452 2.453 2.457	2.451 2.452 2.453 2.457	2.451 2.452 2.453 2.457	2.451 2.452 2.453 2.457	2.451 2.452 2.453 2.457

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 07
NORTHWESTERN CASCADES

SUBPROVINCE NO.

	01	02	03	04	05	06	07
SPECIES ASSOCIATION 1	1.754	2.451	1.754	2.451	2.451	2.451	2.451
	1.769	2.453	1.769	2.453	2.453	2.453	2.453
	1.773		1.773				
	2.451		2.451				
	2.453		2.453				
SPECIES ASSOCIATION 5	2.451	1.758	2.451	1.758	2.451	2.451	2.451
	2.452	1.773	2.452	1.773	2.452	2.452	2.452
	2.453	2.451	2.453	2.451	2.453	2.453	2.453
	2.457	2.452	2.457	2.452	2.457	2.457	2.457
		2.453		2.453			
		2.457		2.457			
		3.652		3.652			
		3.658		3.658			

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 08
NORTHEASTERN CASCADES

SUBPROVINCE NO.

	01	02	03	04	05	06	07	08
SPECIES ASSOCIATION 5	2.451	1.758	2.451	1.758	2.451	2.451	2.451	2.451
	2.452	1.760	2.452	1.760	2.452	2.452	2.452	2.452
	2.453	1.761	2.453	1.761	2.453	2.453	2.453	2.453
	2.457	1.773	2.457	1.773	2.457	2.457	2.457	2.457
		1.775		1.775				
		1.776		1.776				
		2.451		2.451				
		2.452		2.452				
		2.453		2.453				
		2.457		2.457				
		3.652		3.652				
		3.658		3.658				
SPECIES ASSOCIATION 6	2.451	2.451	1.758	2.451	2.451	2.451	2.451	2.451
	2.452	2.452	1.759	2.452	2.452	2.452	2.452	2.452
	2.453	2.453	1.760	2.453	2.453	2.453	2.453	2.453
	2.455	2.455	1.761	2.455	2.455	2.455	2.455	2.455
	2.456	2.456	1.773	2.456	2.456	2.456	2.456	2.456
	2.457	2.457	1.774	2.457	2.457	2.457	2.457	2.457
	3.656	3.656	1.775	3.656	3.656	3.656	3.656	3.656
	3.852	3.852	1.776	3.852	3.852	3.852	3.852	3.852
			1.778					
			2.451					
			2.452					
			2.453					
			2.455					
			2.456					
			2.457					
			3.656					
			3.852					

(CONTINUED)

PROVINCE NO. 08
(CONTINUED)

SPECIES	2.451	2.451	2.451	2.451	1.760	1.758	1.754	2.451
ASSOCIATION	2.452	2.452	2.452	2.452	1.761	1.759	1.760	2.452
7	2.453	2.453	2.453	2.453	1.775	1.760	1.769	2.453
	2.455	2.455	2.455	2.455	1.776	1.773	2.451	2.455
	2.456	2.456	2.456	2.456	2.451	1.774	2.452	2.456
	2.457	2.457	2.457	2.457	2.452	1.775	2.453	2.457
	3.656	3.656	3.656	3.656	2.453	1.778	2.455	3.656
	3.852	3.852	3.852	3.852	2.455	2.451	2.456	3.852
					2.456	2.452	2.457	
					2.457	2.453	3.656	
					3.656	2.455	3.852	
					3.852	2.456		
						2.457		
						3.656		
						3.852		
SPECIES	2.451	2.451	2.451	2.451	2.451	1.760	2.451	2.451
ASSOCIATION	2.452	2.452	2.452	2.452	2.452	1.774	2.452	2.452
8	2.453	2.453	2.453	2.453	2.453	1.775	2.453	2.453
	2.455	2.455	2.455	2.455	2.455	2.451	2.455	2.455
	2.456	2.456	2.456	2.456	2.456	2.452	2.456	2.456
	2.457	2.457	2.457	2.457	2.457	2.453	2.457	2.457
	3.656	3.656	3.656	3.656	3.656	2.455	3.656	3.656
	3.852	3.852	3.852	3.852	3.852	2.456	3.852	3.852
						2.457		
						3.656		
						3.852		
SPECIES	2.456	2.456	2.456	2.456	2.456	2.456	2.456	2.456
ASSOCIATION	2.457	2.457	2.457	2.457	2.457	2.457	2.457	2.457
9	3.852	3.852	3.852	3.852	3.852	3.852	3.852	3.852

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 09
RECENT (HIGH) CASCADES

SUBPROVINCE NO.

	01	02	03	04	05
SPECIES ASSOCIATION 1	2.451 2.453	2.451 2.453	2.451 2.453	2.451 2.453	2.451 2.453
SPECIES ASSOCIATION 2	2.451 2.453 2.454 2.457	2.451 2.453 2.454 2.457	2.451 2.453 2.454 2.457	1.758 1.760 1.773 1.775 2.451 2.453 2.454 2.457 3.652 3.653	2.451 2.453 2.454 2.457
SPECIES ASSOCIATION 5	2.451 2.452 2.457 3.652 3.653 3.658	1.758 1.760 1.761 1.773 1.775 1.776 2.451 2.452 2.457 3.652 3.653 3.658	1.758 1.760 1.761 1.773 1.775 1.776 2.451 2.452 2.457 3.652 3.653 3.658	1.758 1.760 1.761 1.773 1.775 1.776 2.451 2.452 2.454 2.457 3.652 3.653 3.658	1.758 1.760 1.761 1.773 1.775 1.776 2.451 2.452 2.457 3.652 3.653 3.658

(CONTINUED)

PROVINCE NO. 09
(CONTINUED)

SPECIES	2.451	1.758	2.451	2.451	1.758
ASSOCIATION	2.452	1.760	2.452	2.452	1.760
6	2.455	1.761	2.455	2.455	1.761
	2.456	1.773	2.456	2.456	1.773
	2.457	1.775	2.457	2.457	1.775
		1.776			1.776
		2.451			2.451
		2.452			2.452
		2.454			2.454
		2.455			2.455
		2.456			2.456
		2.457			2.457
SPECIES	2.451	1.758	2.451	2.451	2.451
ASSOCIATION	2.452	1.760	2.452	2.452	2.452
7	2.455	1.761	2.455	2.455	2.455
	2.456	1.773	2.456	2.456	2.456
	2.457	1.775	2.457	2.457	2.457
	3.652	1.776	3.652	3.652	3.652
		2.451			
		2.452			
		2.455			
		2.456			
		2.457			
		3.652			
SPECIES	2.451	1.761	2.451	1.761	2.451
ASSOCIATION	2.452	1.770	2.452	1.770	2.452
8	2.455	1.776	2.455	1.776	2.455
	2.456	1.778	2.456	1.778	2.456
	2.457	2.451	2.457	2.451	2.457
		2.452		2.452	
		2.455		2.455	
		2.456		2.456	
		2.457		2.457	

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 10
OKANOGAN HIGHLANDS

SUBPROVINCE NO.

	01	02	03	04	05	06	07
SPECIES ASSOCIATION 5	2.451 2.452 2.457	2.451 2.452 2.457	2.451 2.452 2.457	2.451 2.452 2.457	2.451 2.452 2.457 3.652 3.658	2.451 2.452 2.457	1.758 1.760 1.773 1.775 2.451 2.452 2.457
SPECIES ASSOCIATION 6	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852
SPECIES ASSOCIATION 7	1.758 1.759 1.760 1.761 1.773 1.774 1.775 1.776 2.451 2.452 2.455 2.456 2.457 3.656 3.852	1.758 1.759 1.760 1.761 1.773 1.774 1.775 1.776 2.451 2.452 2.455 2.456 2.457 3.656 3.852	1.758 1.759 1.760 1.761 1.773 1.774 1.775 1.776 2.451 2.452 2.455 2.456 2.457 3.656 3.852	1.758 1.759 1.760 1.761 1.773 1.774 1.775 1.776 2.451 2.452 2.455 2.456 2.457 3.656 3.852	2.451 2.452 2.455 2.456 2.457 3.852	2.451 2.452 2.455 2.456 2.457 3.656 3.852	2.451 2.452 2.455 2.456 2.457 3.852
SPECIES ASSOCIATION 8	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852
SPECIES ASSOCIATION 9	2.456 2.457 3.852	2.456 2.457 3.852	2.456 2.457 3.852	2.456 2.457 3.852	2.456 2.457 3.852	2.456 2.457 3.852	2.456 2.457 3.852

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 11
COLUMBIA BASIN

SUBPROVINCE NO.

	ANY
ANY SPECIES	3.852

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 12
BLUE MOUNTAINS

SUBPROVINCE NO.

	01	02	03	04	05	06	07	08	09	10	11
SPECIES ASSOCIATION 5	2.451 2.452 2.457	2.451 2.452 2.457 3.652 3.658	2.451 2.452 2.457	1.758 1.759 1.760 1.761 1.773 1.774 1.775 1.776 2.451 2.452 2.457 3.652 3.658	1.754 1.758 1.759 1.760 1.761 1.773 1.774 1.775 1.776 2.451 2.452 2.457	2.451 2.452 2.457	2.451 2.452 2.457	2.451 2.452 2.457	2.451 2.452 2.457	2.451 2.452 2.457	2.451 2.452 2.457
SPECIES ASSOCIATION 6	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	1.754 1.758 1.760 1.773 1.775 2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	1.754 1.758 1.760 1.773 2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852

(CONTINUED)

PROVINCE NO. 12
(CONTINUED)

SPECIES ASSOCIATION 7	2.451 2.452 2.455 2.456 2.457 3.656 3.852	2.451 2.452 2.455 2.456 2.457 3.656 3.852	2.451 2.452 2.455 2.456 2.457 3.656 3.852	2.451 2.452 2.455 2.456 2.457 3.852	2.451 2.452 2.455 2.456 2.457 3.852	2.451 2.452 2.455 2.456 2.457 3.656 3.852	2.451 2.452 2.455 2.456 2.457 3.852	2.451 2.452 2.455 2.456 2.457 3.852	2.451 2.452 2.455 2.456 2.457 3.852	2.451 2.452 2.455 2.456 2.457 3.852	2.451 2.452 2.455 2.456 2.457 3.852
SPECIES ASSOCIATION 8	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852	2.451 2.455 2.456 2.457 3.852
SPECIES ASSOCIATION 9	2.456 2.457 3.656 3.852	2.456 2.457 3.656 3.852	2.456 2.457 3.656 3.852	2.456 2.457 3.852	2.456 2.457 3.852	2.456 2.457 3.656 3.852	2.456 2.457 3.852	1.757 1.777 1.778 2.456 2.457 3.852	2.456 2.457 3.852	2.456 2.457 3.852	1.757 1.777 2.456 2.457 3.852

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 13
HARNEY BASIN

SUBPROVINCE NO.

	01	02	03	04	05	06
SPECIES	2.451	2.451	2.451	2.451	2.451	1.758
ASSOCIATION	2.455	2.455	2.455	2.455	2.455	1.759
6	2.456	2.456	2.456	2.456	2.456	1.760
	2.457	2.457	2.457	2.457	2.457	1.761
	3.653	3.653	3.653	3.653	3.653	1.773
	3.852	3.852	3.656	3.852	3.852	1.774
			3.852			1.775
						1.776
						1.778
						2.451
						2.454
						2.455
						2.456
						2.457
						3.653
						3.656
						3.853
SPECIES	2.451	2.451	2.451	2.451	2.451	2.451
ASSOCIATION	2.455	2.455	2.455	2.455	2.455	2.455
7	2.456	2.456	2.456	2.456	2.456	2.456
	2.457	2.457	2.457	2.457	2.457	2.457
	3.852	3.852	3.852	3.852	3.852	3.852
SPECIES	2.451	2.451	2.451	2.451	2.451	2.451
ASSOCIATION	2.455	2.455	2.455	2.455	2.455	2.455
8	2.456	2.456	2.456	2.456	2.456	2.456
	2.457	2.457	2.457	2.457	2.457	2.457
	3.852	3.852	3.852	3.852	3.852	3.852
SPECIES	2.456	2.456	1.758	2.456	2.456	2.456
ASSOCIATION	2.457	2.457	1.759	2.457	2.457	2.457
9	3.652	3.652	1.761	3.652	3.652	3.652
	3.653	3.653	1.773	3.653	3.653	3.653
	3.852	3.852	1.774	3.852	3.852	3.656
			1.776			3.852
			1.778			
			2.456			
			2.457			
			3.652			
			3.653			
			3.656			
			3.852			

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 14
UPPER BASIN AND RANGE

SUBPROVINCE NO.

	01	02	03	04	05	06	07
SPECIES ASSOCIATION 6	1.758	2.452	2.452	2.452	2.452	1.758	1.758
	1.759	2.454	2.454	2.454	2.454	1.759	1.759
	1.760	2.455	2.455	2.455	2.455	1.760	1.760
	1.761	2.456	2.456	2.456	2.456	1.761	1.761
	1.766	2.457	2.457	2.457	2.457	1.766	1.766
	1.773	3.656	3.656	3.656	3.656	1.773	1.773
	1.774	3.852	3.852	3.852	3.852	1.774	1.774
	1.775					1.775	1.775
	1.776					1.776	1.776
	2.452					2.452	2.452
	2.454					2.454	2.454
	2.455					2.455	2.455
	2.456					2.456	2.456
	2.457					2.457	2.457
	3.656					3.656	3.656
	3.852					3.852	3.853
SPECIES ASSOCIATION 7	2.452	2.452	2.452	1.759	2.452	2.452	1.766
	2.454	2.454	2.454	1.760	2.454	2.454	2.452
	2.455	2.455	2.455	1.761	2.455	2.455	2.454
	2.456	2.456	2.456	1.774	2.456	2.456	2.455
	2.457	2.457	2.457	1.775	2.457	2.457	2.456
	3.652	3.652	3.652	1.776	3.652	3.652	2.457
	3.653	3.653	3.653	2.452	3.653	3.653	3.652
	3.656	3.656	3.656	2.454	3.656	3.656	3.653
	3.852	3.852	3.852	2.455	3.852	3.852	3.656
				2.456			3.852
				2.457			
				3.652			
				3.653			
				3.656			
				3.852			
SPECIES ASSOCIATION 8	2.455	2.455	2.455	2.455	2.455	2.455	2.455
	2.456	2.456	2.456	2.456	2.456	2.456	2.456
	2.457	2.457	2.457	2.457	2.457	2.457	2.457
	3.852	3.852	3.852	3.852	3.852	3.852	3.852
SPECIES ASSOCIATION 9	2.456	2.456	2.456	2.456	2.456	2.456	2.456
	2.457	2.457	2.457	2.457	2.457	2.457	2.457
	3.852	3.852	3.852	3.852	3.852	3.852	3.852

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 15
BASIN AND RANGE

SUBPROVINCE NO.

	05
SPECIES ASSOCIATION 9	1.758
	1.759
	1.760
	1.761
	1.773
	1.774
	1.775
	1.776
	2.456
	3.652
	3.653
	3.852

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 16
COWLITZ RIVER BASIN

SUBPROVINCE NO.

	01	02	03	04
SPECIES ASSOCIATION 1	2.451	2.451	1.756	1.756
	3.652	3.652	1.760	1.760
	3.653	3.653	1.769	1.769
			1.775	1.775
			2.451	2.451
			3.652	3.652
			3.653	3.653

TABLE SET IIA
FOR VERIFYING STATEMENT NUMBERS
APPLICABLE TO PRIVATE LAND

PROVINCE NO. 17
WALLOWAS

SUBPROVINCE NO.

	01	02	03	04
SPECIES ASSOCIATION 5	1.758	2.451	2.451	2.451
	1.759	2.452	2.452	2.452
	1.760	2.457	2.457	2.457
	1.773	3.652	3.652	3.652
	1.774	3.653	3.653	3.653
	1.776			
	2.451			
	2.452			
	2.457			
	3.652			
	3.653			
SPECIES ASSOCIATION 6	2.451	2.451	2.451	1.769
	2.455	2.455	2.455	2.451
	2.456	2.456	2.456	2.455
	2.457	2.457	2.457	2.456
	3.852	3.852	3.852	2.457
				3.852
SPECIES ASSOCIATION 7	2.451	1.759	1.759	1.759
	2.452	1.760	1.760	1.760
	2.455	1.761	1.761	1.761
	2.456	1.774	1.774	1.774
	2.457	1.776	1.776	1.776
	3.652	2.451	2.451	2.451
	3.653	2.452	2.452	2.452
	3.852	2.455	2.455	2.455
		2.456	2.456	2.456
		2.457	2.457	2.457
		3.652	3.652	3.652
		3.653	3.653	3.653
		3.852	3.852	3.852
SPECIES ASSOCIATION 8	2.451	2.451	2.451	2.451
	2.455	2.455	2.455	2.455
	2.456	2.456	2.456	2.456
	2.457	2.457	2.457	2.457
	3.852	3.852	3.852	3.852
SPECIES ASSOCIATION 9	2.456	2.456	2.456	2.456
	2.457	2.457	2.457	2.457
	3.852	3.852	3.852	3.852

USER'S WORK FORM

The User's Work Form shown in appendix 6 provides a "master" for making copies. A completed form follows for a hypothetical example of a residues management situation. From the steps and entries shown, one can follow the procedure for use of the form and other portions of this chapter to key out applicable guideline statements. Note that the example involves only timber harvesting by group selection cutting (see Input Block 2). Had road construction also been involved for the planned timber harvest, a second User's Work Form would need to be completed for the road construction activity. Thus, the combined two lists of guideline statements would govern the total residue management situation.

Project name or other identifiers: DANDY SALE

Administrative unit name or other identifiers: EXAMPLE

USER'S WORK FORM

GUIDELINES FOR FOREST RESIDUES MANAGEMENT

This form has been developed to help users sort for guideline statements believed to apply to specified land management situations. It is intended for use with the publication:

Pierovich, John M., Edward H. Clarke, Stewart G. Pickford, and Franklin R. Ward. 1975. Forest residues management guidelines for the Pacific Northwest. Pacific Northwest Forest and Range Experiment Station USDA Forest Service General Technical Report PNW-33.

STEP 1 Enter the information requested in Input Blocks 1 through 5 of this form.

Input Block 1

This work form applies to (circle only one):

PUBLIC LAND   PRIVATE LAND

STEP 2

PUBLIC LAND	PRIVATE LAND
Open Guidelines publication to chapter II, Table Set I (yellow paper)	Open Guidelines publication to chapter II, Table Set II (pink paper)

Input Block 2

This work form applies to (check only one):

____ A. Road construction
____ B. Trail construction
____ C. Campground construction
____ D. Structure construction
____ E. Ski run construction
____ F. Utility right-of-way construction
____ G. Timber harvest by individual tree selection cutting
____ H. Timber harvest by shelterwood cutting
__✓__ J. Timber harvest by group selection cutting
____ K. Timber harvest by clearcutting
____ L. Precommercial thinning
____ M. Commercial thinning
____ N. Type conversion, except rangeland
____ O. Treatment of natural residue
____ P. Treatment of dying and damaged vegetation
____ Q. Rangeland type conversion

USER'S WORK FORM (cont.)

STEP 3 Within the Table Set (I or II) chosen in step 2, turn to the Sorting Set letter corresponding to the letter checked in Input Block 2. Note that there are either four or five tables within this Sorting Set. Refer to Table 1 now and list all statement numbers shown in the box below:

Statement List 1 (from Table 1):

1.502	1.901	2.302	3.812
1.712	1.902	2.303	3.813
1.713	1.903	2.306	3.814
1.717	1.904	2.307	3.815
1.718	1.905	3.601	3.816
1.729	1.906	3.606	3.817
1.730	2.201	3.607	3.818
1.801	2.202	3.804	
1.802	2.205	3.806	
1.803	2.301	3.809	

Input Block 3

This work form applies (circle only one):

where residues will or may be burned	where residues will not be burned

STEP 4 If residues will be or may be burned, refer to Table 2 now and list the statement numbers shown in the box below:

If residues will not be burned, check here and proceed to step 5----- ☐

Statement List 2 (from Table 2):

1.101	1.106	1.111	1.702
1.102	1.107	1.112	2.204
1.103	1.109	1.113	
1.104	1.110	1.701	

USER'S WORK FORM (cont.)

STEP 5 If Input Block 4 is for Private Land, check here and go to Step 6 - ☐

If Input Block 4 is for Public Land and the notation "Skip Table 3" is circled in Input Block 4, check here and go to step 6 - - - - - - - - ☐

If Input Block 4 is for Public Land and a column number is circled in Input Block 4, enter the column number in the space labeled "from Table 3, column ____" in the box below. Find this column number in Table 3 and enter all the statement numbers found there in the box below.

Statement List 3 (from Table 3, column 4):	
1.517	1.527
1.520	
1.521	
1.525	

'S WORK FORM (cont.)

Input Block 4

This work form will be for (circle only one):

Public Land

If for public land, proceed to trace from left to right along the path describing the visual management classification for your project. Circle only the column number indicated.

Private Land

If for private land, skip this block and check here: ____

Column numbers

lic
d

- Area not formally classified under visual management system → 1
- Area formally classified under visual management system
  - Area classified as foreground
    - Area designated for modification
      - Occupancy & wander-through are main use patterns → 2
      - Low-speed pass-by is main use pattern → 3
      - High-speed pass-by is main use pattern → 4
    - Area designated for partial retention
      - Occupancy & wander-through are main use patterns → 5
      - Low speed pass-by is main use pattern
        - Little or no screening → 6
        - Moderate to heavy screening → 7
      - High-speed pass-by is main use pattern
        - Little or no screening → 8
        - Moderate to heavy screening → 9
    - Area designated for retention
      - Occupancy & wander-through are main use patterns → 10
      - Low-speed pass-by is main use pattern
        - Little or no screening → 11
        - Moderate to heavy screening → 12
      - High-speed pass-by is main use pattern
        - Little or no screening → 13
        - Moderate to heavy screening → 14
    - Area designated for preservation → 15
  - Area classified as middle ground
    - Area designated for modification → 16
    - Area designated for partial retention → 17
    - Area designated for retention → 18
    - Area designated for preservation → 19
  - Area classified as background → (Skip Table 3)

Input Block 5

a. Refer to the Forest Residue Type Area maps in the Guidelines publication (chapter II, Figure 1 or 2), and locate the type area for which this work form applies. Enter here the five-digit code for this area below:

Province		Timber Spp. Assoc.	Subprovince	
1	2	7	0	2

b. Refer to the Forest Residue Type Area discussion (Guidelines publication, chapter II). Using your knowledge of the specific area for which this worksheet applies, review the descriptions of the Timber Species Associations and of those geomorphic subprovinces, within your province, for accuracy. Because the Forest Residue Type Area map must be somewhat generalized, you may find a description which better fits your situation.

After your review, enter below a final, confirmed (from part a, above), or revised identifying number.

(CAUTION - use only Subprovince numbers and Timber Species Associations numbers listed as "recognized" for your province):

Province		Timber Spp. Assoc.	Subprovince	
1	2	7	0	4

USER'S WORK FORM (cont.)

STEP 6 Enter the Province number (first two digits in part b of Input Block 5, above) in the space labeled "from Table 4, column ____" in the box below. Then list all statement numbers in this column of Table 4 in the box below.

Statement List 4 (from Table 4, column 12):

~~1.723~~ 1/	~~1.733~~	2.407
~~1.724~~	~~1.734~~	2.408
~~1.725~~	~~1.738~~	2.409
~~1.726~~	2.401	2.410
~~1.727~~	2.402	~~3.603~~
~~1.731~~	2.405	~~3.608~~
~~1.732~~	2.406	3.807

STEP 7 For some management activities, there will be a Table 5. If there is no Table 5 in your sorting set, check here and go to step 8 - ☐

If there is a Table 5, refer back to Input Block 3.

If residues will not be burned, check here and go to step 8 - ☐

If residues will be or may be burned, enter the Province number (first two digits from Input Block 5) in the space labeled, "Table 5, column ___," in the box below.

In the box below, list all statement numbers shown in that column.

Statement List 5 (from Table 5, column 12):

~~1.703~~	~~1.709~~
~~1.706~~	~~1.710~~
~~1.707~~	
~~1.708~~	

1/ Crossed off numbers are explained in steps 8-11.

USER'S WORK FORM (cont.)

STEP 8 If you are using Table Set I, for public lands, turn to Table Set IA (blue paper). If you are using Table Set II, for private lands, turn to Table Set IIA (green paper).

STEP 9 Use the Province number (first two digits from Input Block 5), to locate in your Table Set the appropriate tabulation of statement numbers for your Province.

STEP 10 Within this Province, find the Timber Species Association identifying number (third digit, part b, of Input Block 5). These rows of statement numbers apply to your Timber Species Association. Then use the Subprovince identifying number (last two digits from part b of Input Block 5), to locate the column for your Subprovince.

Use this column and these rows to verify the applicability of statement numbers in Statement Lists 4 and 5. ONLY THE STATEMENT NUMBERS LISTED PREVIOUSLY IN LISTS 4 AND 5 AND THEN FOUND AGAIN HERE ARE VERIFIED. CROSS OUT ALL STATEMENT NUMBERS IN LISTS 4 AND 5 WHICH ARE NOT VERIFIED.

STEP 11 You now have a complete set of Statement numbers (from Lists 1 through 5) which should be applicable to most situations like the one for which you have prepared this form. Use these numbers to locate the actual statements listed in chapter III, p. 135-157, for Public Lands and in chapter III, p. 160-172, for Private Lands. You will want to note carefully all EXCEPTIONS to any statement to determine if your situation may be one for which a certain guideline was not intended to apply.

You may wish to attach to this form a record of departures from recommended guidelines, as well as any other notes regarding modifications or limits you may develop. In this way, this work form and attachments will be available for future reviews of the decisions you have made regarding forest residues management.

DANDY SALE — RECORD
OF DEPARTURES
& NOTES ON RESIDUES
GUIDELINES

1.729	Waiving of suspension requirement to be when exposed mineral soil will not be more than 20% (per exception)
3.815 & 3.816	Will apply — no fuel break involved
2.406	Meet this requirement by post-sale stand improvement project
2.408	Not applicable - not a precommercial thinning

J James
TMA

Chapter III. Public and private guideline statements

USING THIS CHAPTER

Sorting for Application

As previously set forth, the guidelines in this chapter are not intended to be reviewed one after the other for determining possible application. Familiarity with procedures in chapter II is essential for properly sorting these guidelines for application.

Numbering

Prefix numerals.--The prefix numeral for each guideline indicates if it has come from List 1.000, List 2.000, or List 3.000. The prefix is a means of grouping guidelines into logical management components. List 1.000 details statements most concerned with the environmental elements of air, esthetics, and soil and water quality. List 2.000 groups statements intended to protect or minimize damage to the forest from fire, insects, or disease. List 3.000 details statements intended to enhance the forest environment through manipulative practices. They are presented as three separate but interrelated lists.

In the event of conflicts between statements, the land manager's judgment as to which best meets his established objectives and goals with the least environmental disruption must prevail. We recognize that changes in technology, economic conditions, and other external factors could and should force a continual reassignment of priorities. When the guidelines are grouped into like management components from which selections are made, the impact of this continual reordering may be avoided. Thus, when selections are made to meet objectives, guidelines drawn from all three lists should be considered and their applications evaluated.

Series numbering within lists.--The statements originating with each of the nine Technical Panels are numbered in separate hundreds-series to identify them with their sources and to permit orderly revisions or future additions within a series. No rank-ordering within each series is intended or implied.

In addition, the statements listed within each hundreds-series have been assigned to separate serial sets; one for Public and one for Private Lands. The set numbered serially between 01 and 49 is for Public Lands and the set numbered between 51 and 99 is for Private Lands. This allows for similar groupings but still insures that any guideline can be identified with the type of land ownership for which it was intended.

The following is an index to the hundreds-series assigned:

Starting number assigned Public Lands Guidelines	Starting number assigned Private Lands Guidelines	Originating Technical Panel
101	151	Air Quality
201	251	Diseases
301	351	Fire Management
401	451	Insects
501	551	Recreation
601	651	Silviculture
701	751	Soils
801	851	Terrestrial Habitat
901	951	Water Quality and Aquatic Habitat

Judgments

Except as agencies or firms may indicate otherwise, these statements are intended only as guidelines. They were judged initially on a technical basis before being recommended to the Land Management Decisions Panels for policy judgment. They were often modified by the policy review and compilation process.[1/] As products of this intensive judging and modifying sequence, the guidelines may be regarded as generally acceptable for specified situations.

General acceptance is not always an adequate basis for choosing to follow a guideline. Very small differences in local environments may dictate a different course. Intimate knowledge of local situations can be expected to influence applicability of some statements in the judgment of individual land managers. Most Panelists expressed a desire that final determination of application be left to unit managers, and this is the intent of expressing statements as guidelines rather than proposed regulations or standards.

Moreover, the Land Management Decisions Panels judged each statement as to its desirability and attainability. A few were judged as desirable, but not universally attainable (D, NUA). Guidelines, or parts of guidelines, so judged by either the Public or Private Land Management Decisions Panel carry the notation "D, NUA" in parentheses at the end of the statement (see, for example, Guideline 1.112). Individual land managers may temper their own decisions to follow this judgment or to depart from it.

1/ During the compilation process, many statements were edited and rewritten to incorporate additional clarifying language as to intent or measurable results, to consolidate those which were consistently applied to the same situation, and to separate some which were sufficiently diverse to call for independent treatment. In the process, every effort was made to maintain the original intent and context.

References to Documentation

Each statement carries a designation entered in the DOCUMENTATION COLUMN which refers to supporting information in chapter IV. These references may be used to trace each statement to its technical bases, as well as to obtain amplification of the intent of the statement or to provide suggested rules-of-thumb and cross-referencing where needed. The two prefix characters identify the Technical Panel originating the statement, as follows:

AI	Air Quality
RE	Recreation
SO	Soils
TE	Terrestrial Habitat
WA	Water Quality and Aquatic Habitat
DI	Diseases
FI	Fire Management
IN	Insects
SI	Silviculture

PUBLIC LANDS GUIDELINES

Objectives and Goals for Public Lands

One public agency might consistently modify certain statements to be mandatory for its lands in the Northwest, and another might not. The difference of guideline applicability between agencies responsible for management of public lands is founded in differences in the goals and other direction contained in the legislation which established the agencies and authorizes their operations. The following quoted excerpts are provided to show the objectives and activities, as related to these guidelines, of public agencies involved in managing residues on forest lands.

Bureau of Indian Affairs, U.S. Department of the Interior (Office of the Federal Register 1972, p. 261-262):

> Objectives...to actively encourage and train Indian and Alaskan Native people to manage their own affairs under the trust relationship to the Federal Government...full development of their human and natural resource potentials....
>
> Functions...(4) works with them in the development and implementation of programs for their economic advancement and for full utilization of their natural resources consistent with the principles of resource conservation; and (5) acts as trustee of their lands and monies held in trust by the United States, assisting them to realize maximum benefits from such resources.

Bureau of Land Management, U.S. Department of the Interior (Office of the Federal Register 1972, p. 262-263):

> Activities...Public land resources...include timber, minerals, wildlife habitat, livestock forage, public recreation values, and open space. Bureau programs provide for the protection, orderly development, and use of all these resources under principles of multiple use and sustained yield, and for a quality environment. It manages watersheds to protect soil and enhance water quality, develops recreation opportunity on public land....

Forest Service, U.S. Department of Agriculture (Office of the Federal Register 1972, p. 97-98):

> Objectives...Federal responsibility for leadership in forestry...(1) promote and achieve a pattern of natural resource uses that will best meet the needs of people now and in the future; (2) protect and improve the quality of air, water, soil, and natural beauty; (3) help protect and improve the quality of open space environment in urban and community areas; (4) generate forestry opportunities to accelerate rural community growth; (5) encourage the growth and development of forestry-based enterprises that readily respond to consumers' changing needs...(10) expand public understanding of environmental conservation....
>
> Functions and Activities. National Forest System...under the principles of multiple use and sustained yield.... The Nation's tremendous need for wood and paper products is balanced with the other vital renewable resources or benefits.... The guiding principle is the greatest good to the greatest number in the long run.... These lands are protected as much as possible from wildfire, epidemics of disease and insect pests, erosion, floods, and water and air pollution....

National Park Service, U.S. Department of the Interior (Office of the Federal Register 1972, p. 258):[2/]

> Objectives...to administer the properties under its jurisdiction for the enjoyment and education of our citizens, to protect the natural environment of the areas, and to assist the States, local governments, and citizen groups in the development of park areas, the protection of the natural environment, and the preservation of historic properties....

[2/] Although included in these excerpts for comparison purposes, National Park Service participation was not invited in development of these guidelines because of the difference of objectives between this agency and other use-oriented agencies responsible for lands where residues are a recognized challenge. This exclusion does not intend to convey that there are no residue problems in National Parks, but rather, that guidelines for National Parks must be different in many circumstances.

Oregon State Department of Forestry:[3/]

> The objective of the management of State forest lands is to achieve optimum growth and harvest of forest products consistent with the protection of watersheds, fish and wildlife habitat, and recreation and aesthetic considerations. Management plans for all State forest lands will also recognize other appropriate uses, such as grazing, erosion control, mining, research and education, and administrative use; whenever possible, management practices should be designed to provide for such uses without complete elimination of timber harvesting or other uses.

Washington State Department of Natural Resources [n.d.]:

> ...endorses management of State lands to provide the following:
>
> 1. Obtain maximum sustained economic benefits to the trust to which the land is dedicated, while fulfilling basic social obligations to all large forest and range land ownerships.
>
> 2. When not in conflict with the first objective, maximize social benefit to the people of the State....
>
>   ...Maintenance of the environment will be a prime consideration in management of State lands....

Comparison of the above excerpts will show differing emphasis on economic, social, and environmental considerations. These differences will influence the applicability of forest residue guidelines because evaluations of trade offs will be in different contexts. Nevertheless, there exists a common thread of concern for environment. This environmental concern has been evolving over many years from earlier, more exploitative origins; these origins and foundation laws still must often influence the ultimate trade-off decisions to follow or forego environmental protection measures. For example, despite its ever deepening concerns for environmental protection, the Forest Service remains under mandate to provide for the Nation's timber supply, just as it did in 1908 when the following was written about the National Forests:

> National Forests are created to preserve a perpetual supply of timber for home industries, to prevent destruction of the forest cover which regulates the flow of streams, and to protect local residents from unfair competition in the use of forest and range. They are patrolled and protected at Government expense for the benefit of the community and the home builder. (USDA Forest Service 1908.)

Comparison of the 1908 with the 1972 quotation, above, will readily show what important changes have taken place, and yet will also show the agency's continuing mission for timber products as a vital renewable resource.

[3/] Memo to Pacific Northwest Forest and Range Experiment Station from State Forester, September 12, 1974, Salem, Oregon.

Public Lands Guideline Lists

List 1.000 - Public Lands Statements intended to protect the environmental elements--air, soil, water quality, and esthetics

This list contains statements numbered as follows:

1.101 - 1.113, Originating with Air Quality Technical Panel

1.501 - 1.527, Originating with Recreation Technical Panel

1.701 - 1.738, Originating with Soils Technical Panel

1.801 - 1.803, Originating with Terrestrial Habitat Technical Panel[4/]

1.901 - 1.906, Originating with Water Quality and Aquatic Habitat Technical Panel

Statement No.	Public Lands Statements	Documentation
	AIR QUALITY	
1.101	From the standpoint of air quality, methods of treatment other than open burning are preferred. When, however, it has been determined that overall environmental quality is best served by some form of open burning treatment, the burning will be accomplished in compliance with an approved smoke management plan. (See proposed Model Smoke Management Plan in appendix 2.) <u>EXCEPTION</u>: See statement 1.103.	AI-13
1.102	Within a land management administrative unit or subunit, the land manager should determine the annual average number of available burning days and use this determination in establishing burning priorities and objectives that are within the unit's capability to meet air quality standards.	AI-1
1.103	When burning can be accomplished without visible or otherwise objectionable emissions (such as with use of air curtain-type equipment), compliance with the smoke management plan is assumed.	AI-12

4/ These three statements are closely allied with soils and are thus included in List 1.000. Other statements originating with this Panel are found in List 3.000.

Statement No.	Public Lands Statements	Documentation
1.104	Concentrations of forest residues threatening to result in a smoke episode from wildfire are candidates for treatment by burning. When an analysis shows the threat to a smoke-sensitive area from a wildfire is a greater potential nuisance than would be the smoke from the burning operation, burning shall be undertaken.[5/]	AI-10 FI-12
1.105	A firing sequence for prescribed burning must be designed to achieve maximum rate of energy output where a strong convection column is needed for dispersal to higher levels. <u>EXCEPTION</u>: Prescribed underburning which can be accommodated within localized areas where there is no smoke-sensitive area.	AI-11
1.106	When the potential exists for adversely affecting air quality in a smoke-sensitive area, piles or windrows should be mopped up when burning objectives have been met.	AI-7
1.107	Piles and windrows should be made as large as possible within the constraints of safety, piling method, machinery, surrounding resource, and available residue.	AI-8
1.108	If broadcast burning is the prescribed treatment for clearcut residues control, then fuels 4 inches or less in diameter (small end) should ignite readily and support rapid fire spread. In meeting this guideline, fuel moisture sticks may be used to indicate favorable fuel condition.	AI-9
1.109	When smoke from any burning operation may interfere with vehicular traffic, the person responsible for the job will provide safety measures acceptable to local traffic safety law enforcement agencies.	AI-2
1.110	When smoke from any burning operation may interfere with airport operations, the administrator of the smoke management plan should notify the Federal Aviation Administration and the airport manager as far in advance as possible.	AI-3

[5/] See AI-10 (p. 175) in chapter IV for suggested rule-of-thumb to use in analysis.

Statement No.	Public Lands Statements	Documentation
1.111	Where forest residues are to be burned in piles or windrows, such piles and windrows should be sufficiently free of dirt and be compact enough to achieve a hot fire, and should not be burned without fuel or ventilation boosters unless heavy fuels are dry enough to burn unaided.	AI-4
1.112	Stumps over 24 inches top diameter which are to be burned in piles should be split (D, NUA).	AI-5
1.113	Chunking-in, if needed, should be done at intervals sufficient to maintain a hot fire.	AI-6

RECREATION

1.501 In areas not under formal classification as part of a Visual Management System, but where the land manager has determined that scenic values will be given special consideration (such as roadside strips or areas where public use is encouraged), the following goals for residues treatment will apply: RE-1[6/]

a. Disposal of all man-caused residue which is not visually subordinate to the characteristic landscape.

b. Camouflaging of tree stumps.

c. Minimization of scorched tree crowns when fire is used as a treatment.

If public use is less intense but not discouraged, the following goals for residues treatment will be applied on an as-needed basis:

a. Enhancing the appearance of naturalness by treatments which will hasten decomposition where volumes of debris are relatively small.

b. Creating an appearance of "managed concern" by yarding, windrowing, or piling and burning concentrations of residues.

[6/] Because much of the subject matter of esthetics defies exact measurements, this vital element of the environment has been interpreted through what is best known about the recreational use of forests.

Statement No.	Public Lands Statements	Documentation
	c. Avoiding appearances of waste by selling practices which encourage removal of low-value material.	
1.502	All manufactured items (such as oilcans, cable, cable spools) which are discarded will be removed to an agency approved disposal area.	RE-1[6/]
1.503	In all areas formally classified as Preservation,[7/] improvements will be located or relocated so that the man-caused residues resulting from the improvement activity will be minimized.	RE-1[6/]
1.504	A desirable objective for man-caused residues will be 90-percent disposal of all material 1- to 3-inch diameter (large end) and 100 percent of all larger material, provided that any remaining material is less than 3 inches deep. EXCEPTION: When statements 3.605, 3.805, or 3.806 apply, they shall govern.	RE-1[6/]
1.505	All man-caused and disturbed residues which cannot be hidden from view will receive 100 percent disposal treatment.[7/] EXCEPTION: When statements 3.605, 3.805, or 3.806 apply, they shall govern.	RE-1[6/] RE-3
1.506	All residues larger than 2-inch diameter (large end) will receive 100-percent disposal treatment, and all smaller residues must be scattered so as to form an intermittent ground cover no more than 6 inches deep. EXCEPTION: When statements 3.605, 3.805, or 3.806 apply, they shall govern.	RE-1[6/]
1.507	All man-caused and disturbed residues larger than 2-inch diameter (large end) which cannot be hidden	RE-1[6/]

[7/] This statement applies only to National Forest areas formally classified under a Visual Management System. Oregon and Washington have visual management classification systems that do not adapt well to the application of this guideline. No statements have been prepared for areas classified as background under this system. Application of statements can be determined only through use of the methods described in chapter II.

State- ment No.	Public Lands Statements	Documen- tation
	from view of the route of travel will receive 100-percent disposal treatment, and all smaller residues must be scattered so as to form an intermittent ground cover no more than 6 inches deep.	
1.508	When chipping has been selected as a residue disposal treatment, chips should form an intermittent cover in no place thicker than 1 inch.	RE-1[6/]
1.509	When chipping has been selected as a residue disposal treatment, evident chips should form an intermittent cover in no place thicker than 1 inch.	RE-1[6/]
1.510	When chipping has been selected as a residue disposal treatment, any evident chip piles should be visually subordinate to the characteristic landscape.	RE-1[6/]
1.511	A desirable objective will be to dispose of all man-caused and disturbed residues larger than 3-inch diameter (large end). EXCEPTION: When statements 3.605, 3.805, or 3.806 apply, they shall govern.	RE-1[6/]
1.512	A desirable objective will be to dispose of all man-caused and disturbed residues larger than 3-inch diameter (large end) which cannot be hidden.	RE-1[6/]
1.513	Man-caused residue will be removed from the sight of trails, camps, or other frequently used areas. <u>EXCEPTION</u>: Felled trees or naturally down logs which require bucking and are too large to be moved with primitive equipment may be bucked for disposal of all material found within 8 feet horizontal distance from the point of use.	RE-1[6/]
1.514	Treat man-caused and disturbed residues so that they are not evident. (Exact sizes and densities of material which can be left primarily depend on distance from observer, duration of view, type of screen. These call for judgment on a case-by case basis.)	RE-1[6/]
1.515	Treat man-caused and disturbed residues so that they, in combination with other visual effects of the management activity, are visually subordinate to the characteristic landscape.	RE-1[6/]

State-ment No.	Public Lands Statements	Documen-tation
1.516	Treat man-caused and disturbed residues so that they are visually subordinate to the rest of the scene resulting from the activity.	RE-1[6/]
1.517	Cut stumps 12 inches or lower, and camouflage where necessary to meet foreground visual management objectives. EXCEPTIONS: When State law or other safety considerations must be met.	RE-1[6/]
1.518	Evident soil disturbance will be avoided; and for any which does result from residue treatment, restoration will be promptly initiated through repairing and reseeding or replanting which provides for the disturbance to become inconspicuous.	RE-1[6/]
1.519	Evident soil disturbance (such as high-contrast, small bare areas; low-contrast, large bare areas; eroding soil; and pushed-up soil) should remain subordinate to the characteristic landscape. Remedial treatments to achieve this requirement must be judged on a case-by-case basis.	RE-1[6/]
1.520	Soil disturbance should remain visually subordinate to the rest of the scene resulting from the management activity. Remedial treatments to achieve this requirement must be judged on a case-by-case basis.	RE-1[6/]
1.521	When any treatment is undertaken for meeting the objectives of disease control (statement 2.205), of fire management (statements 2.307, 2.308, and 2.309), of insect control (statements 2.402, 2.403, 2.405, 2.406, and 2.410), or of silviculture as a part of recreation management (statements 3.602, 3.603, 3.604, and 3.606), sufficient vegetation should be retained so that the form and texture at the edges of treated areas blend with adjoining, untreated areas. A further requirement of this statement is that any modification to the existing character in areas of treatment not be in evident contrast with nearby, untreated areas.	RE-1[6/] RE-3 RE-4
1.522	When fire is used as a residue treatment, there will be no evident burn scars (such as partly burned piles, charred logs, and scorched trees) by the next recreation use season.	RE-1[6/]

State-ment No.	Public Lands Statements	Documen-tation
1.523	When fire is used as a residue treatment, burn scars (such as partly burned piles, charred logs, burned areas, and scorched trees) will be further treated so as to become inconspicuous by the second recreation use season.	RE-1[6/]
1.524	When fire is used as a residue treatment, burn scars (such as blackened ground and scorched trees or vegetation) will be further treated so as to be visually subordinate to the characteristic landscape by the second recreation use season.	RE-1[6/]
1.525	When fire is used as a treatment, burn scars (such as blackened ground and scorched trees or vegetation) will be further treated so as to be visually subordinate to the scene resulting from the management activity by the second recreation use season.	RE-1[6/]
1.526	When fire is used to reduce fuel buildup or to achieve a specific ecological effect (e.g., meadow perpetuation), goals will include: a. No evident damage to overstory crowns. b. Visual impact of the fire to be subordinate to returning vegetation within 2 years. c. Visual impact of the fire control measures to be minimal and short lived.	RE-1[6/]
1.527	The goal should be to complete work toward meeting the requirements of statements 1.502 through 1.525 according to the following: a. When man-caused residues are created before or during the recreation use season: Immediately, for areas classified as "Retention," within 1 month for areas classified as "Partial Retention," within 1 year for areas classified as "Modification." b. When man-caused residues are created after the recreation use season: Before the next recreation use season for "Retention" and "Partial Retention" areas. c. For other than man-caused residues, or if a or b cannot be met for "Retention" and "Partial Retention" areas: Within 1 year. (EXCEPTION on p. 142.)	RE-1[6/]

Statement No.	Public Lands Statements	Documentation
	EXCEPTION: Where revegetation or greening up of vegetation is expected, a longer time period may be required.	
	SOILS	
1.701	Broadcast burning is not desirable when:	
	a. Soil organic matter is less than 3 percent (D, NUA), or	SO-3
	b. Soil depth is less than 24 inches (D, NUA), or	SO-4
	c. Soil fertility is low (D, NUA), and (EXCEPTION: When fertilizer is applied to proper specifications after burning)	SO-5
	d. Litter depth is less than 1 inch, and (EXCEPTION: In pure ponderosa pine and pure juniper stands of eastern Oregon and Washington)	SO-7
	e. Slope is greater than 60 percent (EXCEPTION: When no more than 20 percent of duff layer will be destroyed).	SO-9
1.702	Broadcast burning will be permitted within 100 feet of live streams provided statements 1.905 and 1.906 can be met.	SO-10
1.703	Broadcast burning should be avoided on fine- or medium-textured soils where more than 20 percent of the area will have exposed mineral soil.	SO-3
1.704	Broadcast burning will not be permitted to burn the duff layer on coarse soils where the available soil moisture holding capacity is less than 2 inches per foot of depth.	SO-2
1.705	Broadcast burning should be avoided when it will burn the duff layer and expose mineral soils on fine-textured soils.	SO-3
1.706	Broadcast burning should be avoided when it will expose mineral soil on more than 20 percent of the area on coarse-textured soils on south slopes where available soil moisture holding capacity is less than 2 inches per foot of depth (D, NUA).	SO-2 SO-6 SO-12

State- ment No.	Public Lands Statements	Documen- tation
1.707	Broadcast burning should be avoided when it will expose mineral soil on more than 20 percent of the area on coarse-textured soils.	SO-2
1.708	Broadcast burning should be avoided when it will expose mineral soil on more than 20 percent of the area on soils of any texture or on any slope where available soil moisture holding capacity is less than 2 inches per foot of depth (D, NUA).	SO-6
1.709	Broadcast burning should be avoided when it will expose mineral soil on more than 20 percent of the area on soils of any texture or on any slope where the exposure is southerly.	SO-12
1.710	Broadcast burning should be avoided where soils are subject to frost heaving.	SO-13
1.711	Broadcast burning should be avoided on all coarse-textured soils.	SO-15
1.712	When fine- or medium-textured soils are present, crushing of residues will be avoided wherever soil moisture in the surface 6 inches exceeds 10 percent.	SO-1
1.713	When slope exceeds 30 percent, crushing of residues by other than systems suspended by cable will be avoided.	SO-8
1.714	On all soils and on all slopes, crushing of residues should be avoided where available soil moisture holding capacity is less than 2 inches per foot of depth.	SO-6
1.715	On all soils and on all slope gradients, crushing of residues should be avoided when it will result in soil shade cover on less than 25 percent of any southerly facing slope.	SO-12
1.716	On coarse-textured soil, crushing of residues will be avoided.	SO-15
1.717	Piling of residues by tracked or wheeled equipment is not desirable when:	
	a. Soil organic matter is less than 3 percent (D, NUA), or	SO-3
	b. Soil depth is less than 24 inches (D, NUA), or	SO-4

State-ment No.	Public Lands Statements	Documen-tation
	c. Soil fertility is low (D, NUA), and	SO-5
	d. Litter depth is less than 1 inch, and	SO-7
	e. Slope is greater than 30 percent.	SO-8
	EXCEPTIONS: This statement does not apply to (a) fuel break construction (statements 2.305 and 2.307) or (b) road prisms. Also, machine piling of materials larger than 3 inches in diameter may be done when the soil is frozen and slopes are less than 30 percent.	
1.718	Piling of residues by tracked or wheeled equipment will be permitted within 100 feet of live streams provided statements 1.905 and 1.906 can be met.	SO-10
1.719	Piling by tracked or wheeled equipment should be avoided when soil texture is fine or medium, and when soil moisture in the surface 6 inches exceeds 10 percent.	SO-1
	EXCEPTION: This statement does not apply in road prisms.	
1.720	Piling by tracked or wheeled equipment should be avoided when soil texture is fine, and when soil moisture in the surface 6 inches exceeds 10 percent.	SO-1
	EXCEPTION: This statement does not apply in road prisms.	
1.721	Piling of residues by tracked or wheeled equipment which will result in soil shade cover of less than 25 percent should be avoided when soil texture is coarse, and when available soil moisture holding capacity is less than 2 inches per foot of depth.	SO-2 SO-6
	EXCEPTION: This statement does not apply in road prisms.	
1.722	Piling by tracked or wheeled equipment which will result in soil shade cover of less than 25 percent on southerly exposure should be avoided when soil texture is coarse.	SO-2 SO-12
	EXCEPTION: This statement does not apply in road prisms.	

State-ment No.	Public Lands Statements	Documen-tation
1.723	Piling by tracked or wheeled equipment which will expose more than 20 percent of the mineral soil should be avoided when soil texture is coarse.	SO-2
1.724	Piling by tracked or wheeled equipment should be avoided on all soils and on all slopes, when available soil moisture holding capacity is less than 2 inches per foot of depth (D, NUA).	SO-6
1.725	Piling by tracked or wheeled equipment which will result in less than 25-percent soil shade cover should be avoided on all soils and on all southerly exposed slopes.	SO-12
1.726	Piling by tracked or wheeled equipment which will result in less than 25-percent soil shade cover should be avoided on all soils and on all slopes where the area is subject to frost heaving.	SO-13
1.727	Piling with tracked or wheeled equipment where the total soil displacement will exceed 15 percent of the area should be avoided on coarse-textured soils and on southerly exposures where available soil moisture holding capacity is less than 2 inches per foot of depth (D, NUA). <u>EXCEPTION</u>: This statement does not apply in road prisms.	SO-2 SO-12
1.728	Piling by tracked or wheeled equipment should be avoided on coarse-textured soils. <u>EXCEPTION</u>: This statement does not apply in road prisms.	SO-15
1.729	Yarding of residues will be accomplished with at least one end of all turns suspended when (D, NUA): a. Soil texture is fine or medium and the soil moisture in the surface 6 inches exceeds 10 percent. b. Slope exceeds 60 percent. <u>EXCEPTIONS</u>: When ground is frozen, the suspension requirements do not apply. Also, in pure ponderosa pine stands of eastern Oregon, the suspension requirement may be waived when exposed mineral soil will not be more than 15 percent of the treated area for fine-textured soils, or not more than 20 percent for other soils. (For this purpose, soil exposure	SO-9

Statement No.	Public Lands Statements	Documentation
	is defined as displacement of litter, live plants, or rock and/or gravel mulch.)	
1.730	When the soil organic matter is less than 3 percent or when the soil fertility is low, yarding of residues will be limited to materials larger than 3 inches in diameter.	SO-5
1.731	When soil texture is coarse, yarding of residues will be accomplished so as to minimize soil disturbance.	SO-2
1.732	For all soil conditions, exposures, and slopes, yarding of residues will be accomplished so that soil shade cover on the treated area is not less than 25 percent (D, NUA).	SO-12
1.733	For all soil conditions, exposures, and slopes where soils are subject to frost heaving, yarding of residues will be accomplished so that soil shade cover on the treated area is not less than 25 percent (D, NUA).	SO-13
1.734	On all soils and on all slopes when available soil moisture holding capacity is less than 2 inches per foot of depth, yarding of residues should be accomplished so as to minimize soil disturbance and should be limited to material larger than 3 inches in diameter and 5 feet long (D, NUA).	SO-6
1.735	On dunal sheet of coarse-textured soils, yarding of residues will be accomplished to avoid ground contact (D, NUA).	SO-15
1.736	When litter depth is equal to or greater than 5 inches and where some surface scarification will be acceptable for reestablishing timber regeneration, ground contact yarding of residues may be used, providing no more than 30 percent of the mineral soil will be exposed.	SO-14
1.737	When soils are of medium or coarse texture, no yarding of residues in contact with the ground will be permitted to result in soil displacement on more than 15 percent of the treated area (D, NUA). EXCEPTION: Soils of basaltic origin.	SO-1 SO-2
1.738	On soil of any texture, on any exposure, and any slope, lopping and scattering of residues will be the preferred treatment, provided the resulting	SO-16

Statement No.	Public Lands Statements	Documentation
	fuel rating for the overall area does not exceed an "MM"[8/] rating, or as defined by land management agency standards; otherwise, preattack planning and fuel break installation will be accomplished per statements 2.306 and 2.307.	
	TERRESTRIAL HABITAT	
1.801	Forest soils which have been exposed by fire or machine should be reseeded while still loose and friable. The seed will consist of ground cover species appropriate to the site, animals benefited, or other proposed use of the land. <u>EXCEPTIONS</u>: This statement does not apply when statements 3.602, 3.603, 3.604, or 3.606 are applicable, or if the seeding would result in fuels exceeding the requirements of statements 2.308 or 2.309.	TE-1
1.802	Areas where slash is buried (see 2.202) should have the topsoil replaced and be seeded to plants appropriate to the site and planned uses.	TE-2
1.803	As a site protection measure when machine piling for burning of residues in or near a stand of trees, soil should not be pushed into the pile. (See also statement 1.111 for similar air quality requirement covering all piled residues.)	TE-4
	WATER QUALITY AND AQUATIC HABITAT	
1.901	Stable residue (that which has become incorporated into streambanks and stream channels) will not be removed unless fish migration is blocked or channel erosion is occurring.	WA-1
1.902	Unstable residues will be removed from streams in a manner meeting requirements of statements 1.904, 1.905, and 1.906, where their presence will:	WA-2 WA-3

[8/] See FI-2 (p. 183) in chapter IV for definition of fuel type classifications and determination of equivalencies.

State-ment No.	Public Lands Statements	Documen-tation
	a. Increase frequency and/or magnitude of flush-out.	
	b. Threaten damage to downstream uses and property.	
1.903	Man-caused residues should not be allowed to enter live streams. When such residues have entered live streams, statements 1.901 and 1.902 apply.	WA-3 WA-5 WA-6 WA-7
1.904	Removal of residues from streams will be accomplished in the manner least damaging to streambanks and channels.	WA-4
1.905	When treating residues along live streams, a goal should be to leave in place sufficient living riparian vegetation to shade the water surface and thus prevent increases in stream temperature in excess of that permitted in Federal, State, and local water criteria contained in: Public Law (P.L.) 92-500, 1972, p. 60; Oregon Administration Rules (OAR) 41-005 to 41-070, 1970, p. 37; Revised Code of Washington (RCW) 90.48, 1973, Sec. 2. EXCEPTION: In the case of seriously disease- or insect-infested stands of timber, the goal may be modified to avoid further deterioration of the affected watershed.[9/]	WA-8 WA-9
1.906	Riparian residues, both live and dead, will not be treated in a manner which would result in:	WA-6 WA-8
	a. Levels of any introduced chemical exceeding established Federal, State, and local water quality criteria contained in: P.L. 92-500, 1972, p. 60; OAR 41-005 to 41-070, 1970, p. 37; RCW 90.48, 1973, Sec. 2.	WA-10 WA-11 WA-12 WA-13
	b. Exposure of streambank soils to erosion.	
	c. Deterioration of fish habitat.	

9/ Land Managers are cautioned that this exception may be at variance with existing laws on occasion. One such occasion is this specific exception.

List 2.000 - Public Lands Statements intended to protect or minimize forest damage from diseases, fire, and insects

This list contains statements numbered as follows:

2.201 - 2.206, Originating with Diseases Technical Panel

2.301 - 2.310, Originating with Fire Management Panel

2.401 - 2.411, Originating with Insects Panel

Statement No.	Public Lands Statements	Documentation
	DISEASES	
2.201	To reduce the incidence of root disease and decay in established trees, no more than 20 percent of timber stand shall be permitted to sustain bark penetrating wounds during residue treatment operations.	DI-1
2.202	To reduce the incidence of infection in a new or established timber stand, residues known to be colonized by root decay fungi such as *Armillaria mellea*, *Fomes annosus*, or *Poria weirii* shall not be buried or worked into the soil as a planned disposal practice.	DI-2
2.203	Freshly cut stumps of all coniferous species located within and immediately adjacent to developed recreation sites and tree seed orchards should be treated with powdered borax to prevent *Fomes annosus* infection.	DI-3
2.204	When underburning is used as a means of residue reduction in coniferous stands, care shall be taken to hold any cambial damage to less than 20 percent of the established trees.	DI-1
2.205	All living dwarf mistletoe-infected trees over 4 feet high remaining after final harvest cutting should be killed and the requirements of statement 2.203 met in areas where applicable.	DI-4
2.206	Before equipment is moved from a Port-Orford-cedar stand infested with *Phytophthora lateralis* to an uninfested stand, soil clumps on such equipment shall be removed by high pressure washing. No forest residue may be moved from an infested to an uninfested stand.	DI-5

State-ment No.	Public Lands Statements	Documen-tation
	FIRE	
2.301	In all categories of value-at-risk fire-planned areas, a goal will be to dispose of all man-caused residue concentrations (such as landings, portable-sawmill debris piles) and to modify the remainder of the area of the activity to a fuel hazard rating equivalent to, or lower than, an MM classification, or as otherwise defined by land management agency standards (D, NUA).	FI-1 FI-2 FI-3 FI-4 FI-5
	EXCEPTION: In areas other than strategic locations identified in preattack planning, where statements are applied calling for treatments benefiting silviculture, soils, or wildlife habitat, these statements will override.	
2.302	In all high and medium value-at-risk fire-planned areas, a goal will be to exceed the minimum treatment set forth in 2.301 by at least returning the area to a fuel hazard rating no greater than that which existed before undertaking any activity, provided the prior rating was lower than MM, or as otherwise defined by land management agency standards (D, NUA).	FI-1 FI-6
2.303	In all high and medium value-at-risk fire-planned areas, residue treatment associated with any man-caused residues will include disposal of snags.	FI-1 FI-8
	EXCEPTION: In areas other than on and adjacent to strategic locations identified in preattack planning (see statement 2.306), statements 3.815 through 3.818 apply.	
2.304	In high value-at-risk fire-planned areas, residues from precommercial thinning should be modified to a fuel hazard rating equivalent to, or lower than, an MM classification, or as otherwise defined by land management agency standards (D, NUA).	FI-1 FI-2 FI-3 FI-4 FI-5
2.305	In medium value-at-risk fire-planned areas, a goal will be to develop preattack plans which include installing and maintaining fuel breaks concurrently with precommercial thinning whenever the fuel hazard exceeds a rating of an MM classification, or as otherwise defined by land management agency standards.	FI-1 FI-5 FI-9 FI-10
2.306	A goal will be to develop fire preattack plans for all areas.	FI-9

State-ment No.	Public Lands Statements	Documen-tation
2.307	In high and medium value-at-risk fire-planned areas, a goal will be to install and maintain shaded fuel breaks in strategic locations (such as along ridgetops and along suitable roads) as determined by fire preattack planning.	FI-1 FI-7 FI-9 FI-10 FI-12
2.308	In high value-at-risk fire-planned areas, a goal will be to reduce natural fuel hazard to a rating equivalent to or lower than an MM classification, or as otherwise defined by land management agency standards.	FI-1 FI-2 FI-3 FI-4 FI-5 FI-7
2.309	In medium or low value-at-risk fire-planned areas, where natural fuel hazards and fire risk are high in concentrated locations, a goal will be to reduce the fuel hazard of the concentrations to a rating equivalent to or lower than an MM classification, or as otherwise defined by land management agency standards (D, NUA).	FI-1 FI-2 FI-3 FI-4 FI-5 FI-7
2.310	Prescribed burning will be the preferred method of fuel hazard reduction, provided no more than 20 percent of established trees will sustain cambial damage (D, NUA).	FI-11
	INSECTS	
2.401	When an epidemic population of the Douglas-fir beetle is present, green Douglas-fir residue 8 inches or larger in diameter should be disposed of, or moved at least 35 feet from the nearest standing Douglas-fir, before the residue is attacked. Residue in selection-cut areas should have highest priority for treatment. If the residue becomes infested, it should be disposed of before the broods emerge (D, NUA).	IN-1
2.402	Whenever an epidemic spruce bark beetle population occurs in an Engelmann spruce stand and the area is accessible, infested merchantable trees should be removed within 1 year of infestation to prevent a beetle outbreak (D, NUA).	IN-2
2.403	All Pacific silver and subalpine fir trees, including advance reproduction, infested with balsam woolly aphid should be felled during cutting operations and/or destroyed during residue treatment.	IN-3

State-ment No.	Public Lands Statements	Documen-tation
2.404	Whenever mountain pine beetles are present in the sugar pine forest type, any windthrown timber in accessible areas should be removed within 1 year of blowdown to prevent a beetle outbreak (D, NUA).	IN-4
2.405	When a mountain pine beetle outbreak occurs in an overmature (80-year-old) lodgepole pine stand, all infested trees as well as all noninfested trees should be removed before the new brood emerges. <u>EXCEPTION</u>: Merchantable noninfested trees needed for shelterwood and regeneration as prescribed by a silviculturist will not be removed.	IN-5
2.406	An accessible overstocked pole-size ponderosa pine stand should be thinned to reduce the basal area, improve tree vigor, and reduce susceptibility to mountain pine beetle attacks.	IN-6
2.407	Ponderosa pine residues infested with pine engraver beetle broods should not be piled against uncut timber.	IN-7
2.408	Precommercial thinning of ponderosa pine should be done in accord with the following: a. If done following overstory removal in the same stand, thinning should be delayed until after emergence of pine engraver beetle broods from the most recent logging slash. b. If there is an existing high hazard of tree-killing by the pine engraver beetle, thinning should not be done in the spring or summer.	IN-8
2.409	Where the western pine beetle is present, green ponderosa pine logging residue larger than 12 inches in diameter (large end) should not be left within 35 feet of standing pine trees.	IN-9
2.410	When western pine beetle is present in an accessible ponderosa pine stand, any infested windthrown or fire-injured trees should be removed before the broods emerge.	IN-10
2.411	To prevent a buildup of Douglas-fir beetle populations, fresh windthrow and fire-injured trees should be removed within a 12-month period. Shaded blowdown poses a greater hazard and should have the highest priority for treatment (D, NUA).	IN-1

List 3.000 - Public Lands Statements intended to enhance the forest environment through manipulative practices

This list contains statements numbered as follows:

3.601 - 3.608, Originating with Silviculture Technical Panel

3.804 - 3.818, Originating with Terrestrial Habitat Technical Panel[10/]

Statement No.	Public Lands Statements	Documentation
	SILVICULTURE	
3.601	Forest residues created by a silvicultural operation should be treated so that crop trees are not damaged and the area is accessible for future harvest or silvicultural activities.	SI-1
3.602	When any timber harvest operation reduces the number of crop trees 11-inch d.b.h. or larger below 70 trees per acre and planting will be the method of reestablishing preferred timber species, the residue should be treated so that at least 350 planting spots and/or established seedlings or saplings are uniformly distributed on each acre. <u>EXCEPTION</u>: That portion of any area needed to meet the requirements of statements 3.805 and 3.806, where applicable, is excluded from this requirement.	SI-1
3.603	When any timber harvest operation reduces the number of crop trees 11-inch d.b.h. or larger below 40 trees per acre and planting will be the method of reestablishing preferred timber species, the residue should be treated so that at least 190 planting spots and/or established seedlings or saplings are uniformly distributed on each acre. <u>EXCEPTION</u>: That portion of any area needed to meet the requirements of statements 3.805 and 3.806, where applicable, is excluded from this requirement.	SI-2

10/ Note that Terrestrial Habitat Technical Panel statements .801 through .803 have been made part of List 1.000.

State-ment No.	Public Lands Statements	Documen-tation
3.604	When either natural or direct seeding is the method of restocking in stands where the number of trees 11-inch d.b.h. or larger is below minimum stocking level (see 3.602 or 3.603 for appropriate minimum stocking level), forest residues should be treated so that enough uniformly distributed mineral soil is exposed to achieve regeneration objectives. <u>EXCEPTION</u>: That portion of any area needed to meet the requirements of statements 3.805 and 3.806, where applicable, is excluded from this requirement.	SI-2
3.605	Where the number of trees 11-inch d.b.h. or larger is below minimum stocking (see 3.602 or 3.603 for appropriate minimum stocking level) after a harvest, 80-cubic-foot or larger residue pieces should be reduced to five or fewer pieces per acre. Smaller material shall be left in place to protect against temperature extremes and to retain soil moisture, provided the requirements of statements 3.602 through 3.604 are also met (D, NUA). <u>EXCEPTIONS</u>: Strategic locations identified by preattack planning are specifically excluded from applicability of this statement. Where statement 3.607 applies, it shall govern.	SI-2 SI-3
3.606	Live residues competing with crop trees should be controlled as follows: a. During the first 5 years after establishment of crop trees, brush species should be controlled as needed before loss of dominance by the crop trees and as needed before there is a marked effect on sunlight and/or available soil moisture necessary for crop-tree survival. b. After the first 5 years, competing live residues should be controlled whenever the height of the competition exceeds two-thirds of crop tree height. <u>EXCEPTIONS</u>: That portion of any area needed to meet the requirements of statements 3.805 and 3.806, where applicable, is excluded from this requirement. When statement 3.812 applies, it shall govern unless statement 3.607 also applies, in which case statement 3.607 takes precedence.	SI-4

Statement No.	Public Lands Statements	Documentation
3.607	Forest residues that encourage buildup of animal populations which will prevent establishment and growth of an adequate number of crop trees should be treated.	SI-5
3.608	Forest residues should be treated so that prescribed fire can be used to control invading vegetation which will reduce growth rate by at least 20 percent and to prepare seed bed for natural or direct seeding.	SI-6
	TERRESTRIAL HABITAT	
3.804	When broadcast burning is used for residue reduction, at least 50 percent of the area should be burned.	TE-3
3.805	When unmerchantable material is yarded in lieu of other treatments on clearcuts used by wildlife, 10 percent of the area should be left suitable for big game cover. (Suitable big game cover in large clearcuts is defined for this purpose as undisturbed residue in an area of at least 5,000 square feet and measuring 3-6 feet high over 70 percent of the area.) Such areas should be distributed throughout the clearcut, preferably placed on locations of low productivity and/or which are inoperable or marginal for tracked or wheeled equipment. <u>EXCEPTIONS</u>: Strategic locations identified by pre-attack planning are specifically excluded from applicability of this statement. Also, if meeting this statement will interfere with crop tree establishment or growth, statement 3.607 will apply.	TE-5
3.806	When residue is treated on slopes of less than 30 percent to enhance domestic livestock and big game habitat, 10 percent of the area will remain suitable for big game cover. When treatment of residue is not otherwise required, such areas should receive treatment so that at least 75 percent of the area not in game cover is left in a condition that will facilitate movement of animals. (Suitable big game cover is defined for this purpose the same as in statement 3.805, except that in partially cut timber stands an equivalency thereto may be determined on the ground from a combination of uncut timber, undisturbed understory vegetation, and residues to be piled.) (EXCEPTIONS on p. 156.)	TE-6 TE-9

State-ment No.	Public Lands Statements	Documen-tation
	EXCEPTIONS: Strategic locations identified by preattack planning are specifically excluded from applicability of this statement. Also, if meeting this statement will interfere with crop tree establishment or growth, statement 3.607 will apply.	
3.807	On designated crucial winter ranges in forested areas with bitterbrush, residue will be treated so that at least 90 percent of the bitterbrush plants survive. (Survive means that plants remain alive and have the ability to sprout the following year.)	TE-7
3.808	In the lodgepole-bitterbrush community, at least 50 percent of the original bitterbrush plants must survive logging and residue treatment. (Survive means that plants remain alive and have the ability to sprout the following year.)	TE-8
3.809	On designated livestock and big game trails and along all fence lines, 100 percent of all logging and/or land clearing residue larger than 3-inch diameter will be removed and the remaining material will not exceed 6-inch depth.	TE-9
3.810	When removing encroaching trees for preservation of large huckleberry fields, three to five fir or hemlock trees per acre will be retained.	TE-10
3.811	On clearcuts where temporary huckleberry production is proposed, logs larger than 20-inch diameter and 20-foot length will be removed and the area broadcast burned.	TE-11
3.812	Where silvicultural planning calls for chemical or other control of 10-acre or larger brushfields important for wildlife habitat, not more than one-half of each area should be treated in any 5-year period. If a brushfield exceeds 100 acres, treatment will be discontinuous throughout the area.	TE-12
	EXCEPTIONS: Strategic locations identified by preattack planning are specifically excluded from applicability of this statement. Also, if meeting this statement will seriously interfere with crop tree establishment or growth, statement 3.607 will apply.	
3.813	Where forest residue is chipped, depth of chips in areas expected to grow vegetation shall not exceed 1 inch.	TE-13

Statement No.	Public Lands Statements	Documentation
3.814	When residues are windrowed, breaks will be provided for passage of big game animals and/or livestock whenever windrows cross a natural route of travel. Breaks will be about 10 feet wide and at intervals of not more than 200 feet.	TE-14
3.815	Where there are snags in partial cut areas, an average of two snags per acre should be left.11/ Unmerchantable snags that pose a serious fire or safety hazard will be removed. EXCEPTION: This statement is specifically excluded from application to areas on and adjacent to strategic locations identified in preattack planning (see statements 2.303 and 2.306).	TE-15
3.816	Where cull trees in the dominant crown position are found in partial cut areas and bird habitat requirements need to be met, at least one but preferably two to five cull trees should be left per acre. EXCEPTION: In areas on and adjacent to strategic locations identified in preattack planning, cull trees to be left will exclude those judged likely to become snags or snag tops during the interval before the next cutting cycle (see statements 2.303 and 2.306).	TE-15 TE-16
3.817	When possible, at least one stub per acre, less than 12 feet high, will be left in clearcut areas. EXCEPTION: This statement is specifically excluded from application to areas on and adjacent to strategic locations identified in preattack planning (see statements 2.303 and 2.306).	TE-15
3.818	Snags should be left in groups of two to five or more per acre within leave strips bordering clearcut areas. EXCEPTION: This statement is specifically excluded from application to areas on and adjacent to strategic locations identified in preattack planning (see statements 2.303 and 2.306).	TE-15

11/ Land managers are cautioned that there are safety laws and other laws relative to this statement.

PRIVATE LANDS GUIDELINES

Objectives and Goals for Private Lands

Nearly all forest land owners regard proper land management as a responsibility to society. Wood and wood-fiber building materials and other products from private forest lands contribute significantly to the comfort and well-being of mankind and will gain in importance as social and economic costs of substitute materials continue to escalate. In developing guidelines for private lands, the Private Lands Management Decisions Panel recognized a need to maintain a realistic balance between all of man's needs.

Private property rights and resource ownership have been and are important factors in the economic development and strengths of the United States.[12/] This pride of ownership and the income derived from forest resource uses and manufacturing products have provided key incentives to improve forestry. Benefits from forest land can accrue to private owners only as incomes exceed costs. Esthetic benefits and opportunities for recreation are achieved on private land as byproducts. Uneconomic residue treatments over and beyond that necessary for hazard reduction and site preparation can thus have little need or intrinsic value in management of private land except where public good will is involved. Tree farmers believe that the presence of all stages of a productive vigorous forest on their properties, including the small part of the dynamic natural mosaic that is being harvested, is both necessary and pleasing to see on working tree farms.

Private forest land ownership encompasses a large number of individuals and corporations with land holdings of many different sizes. Quite obviously, management objectives will vary with different ownerships. Private forest land holdings may be as little as 5 acres or as large as hundreds of thousands of acres. Management objectives may vary from retention for esthetic reasons to commercial timber production. Ownership may vary from absentee individual owners to large corporations with well-equipped forestry staffs. Such a diversity of owners and objectives also reflects a difference in physical and financial capabilities to carry out prescribed forest practices.

Any guideline statements written for forest residue reduction on these lands must take into account this diversity of ownerships, objectives, and capabilities through flexibility. In some instances, financial incentives for accomplishing certain stated goals are necessary. Some guidelines must, of necessity, be simply stated as worthy goals to be attained if they are within the landowner's objectives and capabilities. On the other hand, some should be stated as minimum requirements necessary to insure the shared responsibility for protection of contiguous lands, flow-through streams, ambient air quality, and fish and wildlife. The Panel members believed, however, that hard and fast rules that go beyond achieving these specific purposes, and that interfere with the landowner's right to manage and use his property in accordance with his objectives, would not be workable. They also recognized that loss of private

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12/ See also the discussion of private property and its relation to the doctrine of natural rights, FI-14 (p. 196) of chapter IV.

property rights must often be compensated for and that any undue requirements placed on private lands for the public benefit should thus be more appropriately paid for by the public.

The evolution of Forest Practices Acts within the States of Oregon and Washington and the development of self-regulating forest practice rules by committees of private forest land owners are a matter of special pride. They are also evidence of a high level of cooperation that exists between these individual or corporate owners and the public regulatory agencies, progressing steadily forward since the late 1930's. It was then that better economic stability and a diminished danger of loss from fire provided a solid basis for planned reforestation.[12/]

The Private Lands Management Decisions Panel has carefully considered many technical recommendations for forest residue reduction within the brief time and resources available to it. It has accepted many of the technical recommendations as generally desirable, yet has found it necessary to reject others as going beyond the necessary environmental objectives for private lands, and as interfering with the flexibility of management needed for these lands. This chapter reflects the desire of Panel members to press forward in achieving retention of ecological and environmental integrity on forest lands in the Pacific Northwest.

Private Lands Guideline Lists

List 1.000 - Private Lands Statements intended to protect the environmental elements--air, soil, water quality, and esthetics

This list contains statements numbered as follows:

1.151 - 1.163, Originating with Air Quality Technical Panel

1.551, Originating with Recreation Technical Panel

1.751 - 1.778, Originating with Soils Technical Panel

1.851, Originating with Terrestrial Habitat Technical Panel[13/]

1.951 - 1.956, Originating with Water Quality and Aquatic Habitat Technical Panel

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13/ This statement is closely allied with soils and is thus included in List 1.000. Other statements originating with this Panel are found in List 3.000.

State-ment No.	Private Lands Statements	Documen-tation
	AIR QUALITY	
1.151	Whenever it has been determined that overall environmental quality is best served by providing some kind of fire treatment of forest residues, such burning will be done in conformity with the smoke management plan specified by State law (see proposed Model Smoke Management Plan in appendix 2).	AI-13
1.152	Within a land management administrative unit or subunit, the land manager should determine the annual average number of available burning days and use this determination in establishing burning priorities and objectives that are within the unit's capability to meet air quality standards.	AI-1
1.153	When burning can be accomplished without visible or otherwise objectionable emissions (such as with use of air curtain type equipment), compliance with the smoke management plan is assumed.	AI-12
1.154	Concentrations of forest residues threatening to result in a smoke episode from wildfire are candidates for treatment by burning. When analysis shows the threat to a smoke-sensitive area from a wildfire is a greater potential nuisance than would be the smoke from the burning operation, burning may be undertaken.	AI-10 FI-12
1.155	A firing sequence must be designed to achieve maximum rate of energy output where a strong convection column is needed for smoke dispersal at high levels.	AI-11
1.156	Piles or windrows must be mopped up when burning objectives have been met.	AI-7
1.157	Piles or windrows should be made sufficiently large, consistent with safety considerations, to afford complete combustion within the constraints of piling method, machinery, and surrounding stand.	AI-8
1.158	If broadcast burning is the prescribed treatment for clearcut residue control, fuels 4 inches and under should readily ignite and support rapid spread. In meeting this requirement, fuel moisture sticks may be used to indicate favorable fuel condition.	AI-9
1.159	When treatment is to be by burning and smoke from any burning operation may interfere with vehicular traffic, the person responsible for the job will	AI-2

State-ment No.	Private Lands Statements	Documen-tation
	provide flagmen, signs, and other measures acceptable to local traffic safety law enforcement agencies.	
1.160	When smoke from any burning operation may interfere with airport operations, the administrator of the smoke management plan should notify the Federal Aviation Administration and the airport manager as far in advance of burning as possible.	AI-3
1.161	Where residues are to be burned in piles or windrows, such must be sufficiently free of dirt and be compact enough to achieve a fire sufficiently hot to meet smoke management objectives.	AI-4
1.162	Chunking-in, if required, should be done at intervals sufficient to maintain a hot fire.	AI-6
1.163	When no alternative to burning is available, residue may be left if, in the judgment of the land manager, the risk of a wildfire smoke episode is acceptably low.	AI-10
	RECREATION	
1.551	Where the forest land manager has determined that scenic values will be given special consideration (as in roadside strips or where public use is encouraged), objectionable forest residues should be modified in a manner which will minimize the time required to revegetate the area and enhance its appearance.	RE-2
	SOILS	
1.751	Broadcast burning is not desirable when:	
	a. Soil organic matter is less than 3 percent, or	SO-3
	b. Soil depth is less than 24 inches, or	SO-4
	c. Soil fertility is low.	SO-5
	EXCEPTION: When fertility alone limits broadcast burning, alternatives may be either to burn and then apply fertilizer to upgrade fertility or to burn and accept a temporary lessening of timber growth as a trade off for protection against fire, insects, and disease.	

Statement No.	Private Lands Statements	Documentation
1.752	Broadcast burning is generally not advisable when litter depth is less than 1 inch. <u>EXCEPTION</u>: In pure ponderosa pine and pure juniper stands of eastern Oregon and Washington.	SO-7
1.753	Broadcast burning should be used on slopes greater than 60 percent only where necessary to abate an extreme fire hazard or to accomplish a silvicultural objective. In all cases, care must be taken to insure that the humus layer is not destroyed by a fire hotter than necessary.	SO-9 FI-11 FI-12 SI-6
1.754	Broadcast burning is permitted on fine- and medium-textured soils providing the duff layer is not destroyed.	SO-1
1.755	Broadcast burning should be done with reasonable precautions taken to protect the duff layer on coarse soils where the available soil moisture holding capacity is less than 2 inches per foot of depth.	SO-2
1.756	Broadcast burning should be done with reasonable precautions taken to protect the duff layer on fine-textured soils.	SO-1
1.757	When broadcast burning is done, reasonable precautions should be taken to protect the duff layer on south slopes where soil texture is coarse and available soil moisture holding capacity is less than 2 inches per foot of depth.	SO-2 SO-6 SO-11 SO-12
1.758	Broadcast burning should be done with reasonable precautions taken to protect the duff layer where the soil texture is coarse.	SO-2 SO-11
1.759	Broadcast burning should be performed in a manner that will not destroy the duff layer on soils of any texture or on any slope where the soil moisture holding capacity is less than 2 inches per foot of depth.	SO-6 SO-11
1.760	Broadcast burning should be done only when reasonable precautions are taken to protect the duff layer on soils of any texture and on any slope where the exposure is southerly.	SO-11 SO-12
1.761	Broadcast burning is not recommended at high elevations where soils are subject to frost heaving.	SO-13

State-ment No.	Private Lands Statement	Documen-tation
1.762	Lopping and scattering shall be the preferred method of treatment on coarse-textured soils. EXCEPTION: When in conflict, the State requirements shall govern.	SO-15
1.763	When fine- or medium-textured soils are wet, it is good practice to avoid crushing of residues (i.e., moisture exceeds 10 percent in the top 6 inches).	SO-1
1.764	When the slope exceeds 30 percent, crushing of residues by other than systems suspended by cable should be avoided.	SO-8
1.765	On any slope or on soil of any texture, and where crushing is the only available alternative for residue treatment, no less than a 25-percent soil shade cover should be left where the available soil moisture holding capacity is less than 2 inches per foot of depth.	SO-6
1.766	On any slope or on soil of any texture, crushing of residues will be permitted provided sufficient soil shade cover is maintained for successful seedling establishment.	SO-12 SI-3
1.767	Machine-piling of residues is acceptable provided material of less than 3 inches in diameter is left on the ground when:	
	a. Soil organic matter is less than 3 percent.	SO-3
	b. Soil depth is less than 24 inches.	SO-4
	c. Soil fertility is low.	SO-5
	d. Litter depth is less than 1 inch.	SO-7
1.768	Machine-piling of residues on slopes of over 35 percent should be discouraged except where such operation can be performed without permanent or long lasting soil damage. EXCEPTION: In the Siskiyou Province (Province 03), 30 percent should be the maximum in this statement.	SO-8
1.769	When soil texture is fine or medium, and when available soil moisture in the surface 6 inches exceeds 10 percent, machine-piling of residues should be avoided. (EXCEPTIONS on p. 164.)	SO-1

State-ment No.	Private Lands Statements	Documen-tation
	EXCEPTIONS: a. Road rights-of-way. b. Equipment exerting less than 3½ pounds per square inch of bearing surface.	
1.770	When soil texture is fine and when soil moisture in the surface 6 inches exceeds 10 percent, machine-piling of residues should be avoided to prevent compaction of soil. EXCEPTIONS: a. Road rights-of-way b. Equipment exerting less than 3½ pounds per square inch of bearing surface.	SO-1
1.771	When soil texture is coarse and when soil moisture holding capacity is less than 2 inches per foot of depth, machine-piling of residues will be permitted provided sufficient soil shade cover is maintained for successful seedling establishment.	SO-2 SO-6
1.772	When soil texture is coarse, machine-piling of residues will be permitted provided sufficient soil shade cover is maintained for successful seedling establishment on southerly exposures.	SO-2 SO-12
1.773	When soil texture is coarse, machine-piling should not remove the duff layer.	SO-2
1.774	On all soils and on all slopes, when available soil moisture holding capacity is less than 2 inches per foot of depth, machine-piling of residues will be permitted provided sufficient soil shade cover is maintained for successful seedling establishment.	SO-6
1.775	On all soils and on all southerly exposed slopes, machine-piling will be permitted provided sufficient soil shade cover is maintained for successful seedling establishment.	SO-12
1.776	At high elevations and on all soils and all slopes where the area is subject to frost heaving, machine-piling of residues will be permitted provided sufficient soil shade cover is maintained for successful seedling establishment.	SO-13

State-ment No.	Private Lands Statements	Documen-tation
1.777	On coarse-textured soils and on southerly exposures where available soil moisture holding capacity is less than 2 inches per foot of depth, machine-piling of residues is not desirable where the total soil displacement from all treatments will exceed 15 percent of the area.	SO-2 SO-12
1.778	On soil of any texture, on any exposure and any slope, lopping and scattering is the preferred method of treating forest residues unless otherwise specifically excluded by preceding statements.	SO-16
	TERRESTRIAL HABITAT	
1.851	As a site protection measure when machine-piling for burning of residues in or near a stand of trees, care should be taken to minimize soil being pushed into the piles of debris. (See statement 1.161, for similar air quality requirement covering all piled residues.)	TE-4
	WATER QUALITY AND AQUATIC HABITAT	
1.951	Generally, stable residue (that which has become incorporated into streambanks and stream channels) should not be removed unless fish migration is blocked or channel erosion is occurring and then only if approval for the removal is secured from the State fishery agency.	WA-1
1.952	Man-caused residues will not be allowed to remain in perennial streams, provided their removal is in compliance with State law and their removal will not damage streambanks and channels, when their presence will result in: a. Streambank erosion before, during, or after stream clearance operations. b. Reduction of surface dissolved oxygen levels below that required by State law. c. Deposition of quantities of fine debris on the streambed which will decrease dissolved oxygen levels or reduce waterflow in the subgravel environment below levels required by State law.	WA-3 WA-4 WA-5 WA-6 WA-7

Statement No.	Private Lands Statements	Documentation
1.953	When residues are treated along perennial streams, sufficient live riparian residues (streambank shrubs and trees) providing shade to the water surface should be left in place to prevent unacceptable increases in stream temperature, except as permitted in established Federal and State water quality criteria contained in Public Law 92-500, 1972, p. 60; Oregon Administration Rules (OAR) 41-005 to 41-070, 1970, p. 37; Revised Code of Washington (RCW) 90.48, 1973, Sec. 2.	WA-8
1.954	Riparian residues, live and dead, will not be treated in any manner which will result in: a. Levels of any introduced chemical exceeding established Federal and State water quality criteria contained in Public Law 92-500, 1972, p. 60; OAR 41-005 to 41-070, 1970, p. 37; RCW 90.48, 1973, Sec. 2. b. Deterioration of streamside environment below levels adequate to support native, resident fish. (See also statement 2.355.)	WA-4 WA-5 WA-6 WA-8 WA-10 WA-12 WA-13
1.955	When prescribed fire is used for removal of residues from side slopes, the following principles should be recognized to minimize addition of sediment and chemicals to water: a. Broadcast burning on steep topography may result in increased bare soil and accelerate natural downslope movement of soil particles. b. Intensity of fire can be controlled so that not more than 10 percent of an area is burned to the mineral soil. Excessively steep slopes over 80 percent should not be burned. c. Controlled broadcast burning of residues on a steep, 100-percent logged watershed can increase the concentration of some chemicals above water quality standards for brief periods and in local areas.	WA-10
1.956	Dissolved chemicals in streams are expected to increase in proportion to the amount of drainage burned. In this context, it must be recognized that when water from treated areas joins water from untreated areas of a watershed, dilution may be expected to reduce dissolved chemical amounts to within established water quality standards.	WA-10

List 2.000 - Private Lands Statements intended to protect or minimize damage to the forest from diseases, fire, and insects

This list contains statements numbered as follows:

2.251 - 2.252, Originating with Diseases Technical Panel

2.351 - 2.357, Originating with Fire Management Panel

2.451 - 2.457, Originating with Insects Panel

Statement No.	Private Lands Statements	Documentation
	DISEASES	
2.251	It is a desirable practice after harvesting to kill all dwarf mistletoe-infected residual trees over 4 feet high.	DI-4
2.252	Before equipment is moved from a Port-Orford-cedar stand infested with *Phytophthora lateralis* to an uninfested stand, soil clumps on such equipment should be removed by high pressure washing. No forest residue should be moved from an infested to an uninfested stand.	DI-5
	FIRE	
2.351	The use of prescribed fire is to be encouraged for fuel hazard reduction and silviculture whenever it is not specifically excluded by other private lands statements.	FI-11 FI-12 SI-6
2.352	The land manager should work with the appropriate protection organization to evaluate each area of land in terms of its threat to and from adjoining lands as a basis for determining the appropriate degree of fuel hazard reduction.	FI-14
2.353	Prefire planning is desirable as a vital preparedness measure undertaken cooperatively with the appropriate protective organization.	FI-9 FI-14
2.354	Fire risk and values at stake should be evaluated by individual owners or by contiguous owners working together. Potential losses due to fire can be mitigated by closures to public entry during periods of high fire danger.	FI-13 FI-14

Statement No.	Private Lands Statements	Documentation
2.355	When fire risk is sufficiently high and when closures to public entry will not adequately mitigate the potential for losses due to fire, individual owners or contiguous owners working together with the appropriate protection organization, and in accordance with existing State regulation, should modify fuel concentrations and take such other measures as appropriate to reduce the hazard.	FI-1 FI-2 FI-3 FI-4 FI-12 FI-14
2.356	Snags should be removed in conformance with the land manager's objectives and State forest law.	FI-8
2.357	The trade off of holding fuel hazard buildup to acceptable levels must be an element of determination when evaluating the use of forest chemicals to prevent tree mortality from insect or disease epidemic along with the requirements of Statement 1.954.	FI-1 FI-2 FI-3 FI-4 FI-8 WA-10
	INSECTS	
2.451	Where an epidemic Douglas-fir beetle population is present and when the State Forester declares a zone of epidemic insect infestation for which public funds are available to undertake control as a benefit to all forests, green infested Douglas-fir residue 8 inches and larger in diameter should be disposed of or moved at least 35 feet from the nearest residual Douglas-fir before broods emerge.	IN-1 IN-11
2.452	Where an epidemic spruce bark beetle population is present and when the State Forester declares a zone of epidemic insect infestation for which public funds are available to undertake control as a benefit to all forests, action should be taken to remove the merchantable stemwood and infested trees within the first full operating season to prevent further beetle outbreak.	IN-2
2.453	In areas of Pacific silver and subalpine firs where there is an infestation of balsam woolly aphid and when the State Forester declares a zone of epidemic insect infestation for which public funds are available to undertake control as a benefit to all forests, all infested trees, including advance reproduction, should be felled during cutting operations and disposed of during residue treatment.	IN-3 IN-11

Statement No.	Private Lands Statements	Documentation
2.454	When an epidemic mountain pine beetle population is present and when the State Forester declares a zone of epidemic insect infestation for which public funds are available to undertake control as a benefit to all forests, action should be taken to remove merchantable windthrow within 1 year after the blowdown to prevent a beetle outbreak.	IN-4 IN-11
2.455	When a mountain pine beetle outbreak occurs in an overmature (80- to 100-year-old) lodgepole pine stand and when the State Forester declares a zone of epidemic insect infestation for which public funds are available to undertake control as a benefit to all forests, all infested trees as well as all noninfested merchantable trees should be removed before the new brood emerges. EXCEPTION: Merchantable noninfested trees needed for shelterwood and regeneration as prescribed by a silviculturist may be allowed to remain.	IN-5
2.456	It is desirable that overstocked ponderosa pine pole-size stands be thinned to reduce the basal area to improve tree vigor and reduce susceptibility to mountain pine beetle attacks, provided an economic market is available.	IN-6
2.457	Where an epidemic western pine beetle population is present and when the State Forester declares a zone of epidemic insect infestation for which public funds are available to undertake control as a benefit to all forests, green logging residue larger than 12 inches in diameter should not be left within 35 feet of remaining pine trees larger than 20-inch d.b.h.	IN-9

List 3.000 - Private Lands Statements intended to enhance the forest environment through manipulative practices

This list contains statements numbered as follows:

3.651 - 3.659, Originating with Silviculture Technical Panel

3.852 - 3.854, Originating with Terrestrial Habitat Technical Panel[14/]

Statement No.	Private Lands Statements	Documentation
	SILVICULTURE	
3.651	Forest residues will be treated, rearranged, or disposed of in such a manner that adequate regeneration may be accomplished and in accordance with the minimum requirements of the State Forest Practices Act.	SI-1 SI-2 SI-3
3.652	When the number of trees 11-inch d.b.h. or larger is below minimum stocking level and when seeding is to be practiced or natural regeneration will be the means of restocking, forest residues should be treated so that enough uniformly distributed mineral soil is exposed to achieve regeneration objectives of State Forest Practices Act.	SI-2
3.653	To the degree that regeneration is not inhibited and an unacceptable fire hazard created, smaller material may be left in place to protect against temperature extremes, to retain soil moisture, to stabilize soil movement, to provide nutrients, and to reduce the establishment of competing vegetative cover. EXCEPTION: Where such material may be within a flood plain and may subsequently enter live streams, it should not be left.	SI-2 SI-3
3.654	Live residues competing with crop trees should be controlled: a. During the first 5 years after establishment of crop trees, brush species will be controlled as needed before loss of dominance by the crop trees and as needed before there is a marked effect on sunlight and/or available soil moisture necessary for crop-tree survival and establishment.	SI-4

14/ Note that Terrestrial Habitat Technical Panel Statement .851 was made part of List 1.000.

Statement No.	Private Lands Statements	Documentation
	b. When it appears that live residues will inhibit the establishment and/or development of a forest crop, such residues should be controlled.	
3.655	Forest residues should be treated where they encourage animal populations which will prevent establishment and growth of an adequate number of crop trees.	SI-5
3.656	When prescribed fire is to be used for future control of invading vegetation, including conifer trees which would significantly reduce the growth of crop trees, or for seed bed preparation for natural or direct seeding, forest residues should first be reduced or rearranged to the point that residual crop trees will not suffer fire damage.	SI-6
3.657	Where forest residues are to be treated or rearranged after precommercial thinning to accomplish fire management objectives, the residues should be arranged so that residual trees are not damaged and are accessible for future harvest.	DI-1 SI-1
3.658	Sufficient residue should be retained to provide nutrients, conserve soil moisture, and reduce establishment of competing vegetation.	SI-3 SO-5
3.659	Where slopes exceed 50 percent, sufficient amounts of dead residue and/or uniformly distributed live residue should be left to reduce soil movement that prevents seedling establishment.	SI-3 SO-8
	TERRESTRIAL HABITAT	
3.852	On designated crucial winter ranges used by big game and/or domestic livestock in forested areas with bitterbrush, residue will be treated so that 90 percent of the bitterbrush plants survive logging and residue disposal. (Survive means that plants may be damaged but remain alive above ground and have the ability to sprout, producing new growth the following year.) (D, NUA)	TE-7
3.853	At least 50 percent of the original bitterbrush plants must survive logging and residue disposal in the lodgepole-bitterbrush community. (Survive means that plants may be damaged but remain alive above ground and have the ability to sprout, producing new growth the following year.) (D, NUA)	TE-8

State-ment No.	Private Lands Statements	Documen-tation
3.854	When residues are windrowed, breaks should be provided to afford passage of big game animals and/or livestock whenever windrows will cross a natural route of travel to water and at intervals of not more than 200 feet. Breaks will be about 10 feet wide.	TE-14

LITERATURE CITED

Office of the Federal Register
1972. United States Government organization manual 1972/73. Natl. Arch. & Rec. Serv., Gen. Serv. Adm. 809 p.

USDA Forest Service
1908. The use book--regulations and instructions for the use of the National Forests. 341 p. Washington, D.C.

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[n.d.] Departmental manual. Olympia, Wash.

Chapter IV. Documentation

The purposes of this chapter are to: (1) provide land managers with additional information and "rules-of-thumb" which may make application of the guideline statements easier, and in some cases, more meaningful; (2) help policymakers evaluate the basis for guideline statements; (3) identify the basis for guidelines--either documented research or consensus of specialists--so that it may be compared with conflicting or later information; and (4) help persons responsible for assigning research and development priorities.

Skeleton discussions and some literature citations were initially supplied by each Technical Panel as documentation for its recommended guideline statements. In some cases, only simple editing has been done to the materials supplied. In other cases, the compilers have interpreted and made reference to sources not available to the Technical Panels in the short time they had to do their work. Several completely new documenting statements were added by the compilers. Some of these were necessary where Land Management Decision Panels extensively modified or added to a guideline statement to resolve conflicts; others were called for as a result of the further literature review made by the compilers. Thus, although the entire compilation has been reviewed technically subsequent to compilation, the final responsibility for proper documentary interpretation rests with the compilers.

Following is an index to the guideline supporting information. Each item is identified with a prefix and number. These correspond to those shown in the DOCUMENTATION column of guideline statements in Chapter III. The prefix identifies the originating Technical Panel:

Prefix	Technical Panel
AI	Air Quality Panel
DI	Diseases Panel
FI	Fire Management Panel
IN	Insects Panel
RE	Recreation Panel
SI	Silviculture Panel
SO	Soils Panel
TE	Terrestrial Habitat Panel
WA	Water Quality and Aquatic Habitat Panel

AI--AIR QUALITY GUIDELINES SUPPORTING INFORMATION

AI-1 Need for Local Climatologies

There is a seeming tendency to plan for more disposal of residues by burning than can be accommodated under manpower and related constraints in the average yearly total number of days when conditions are favorable for both burning and proper smoke dispersal. A climatological basis is needed to indicate the probable number of days annually when favorable burning and smoke dispersion conditions may be expected for different types of burning on different administrative units. A method of accomplishing this has been demonstrated (Cramer and Westwood 1970) which should be adapted to local situations in each land management administrative unit.

AI-2 Vehicular Traffic Hazard

Traffic congestion and accidents have occurred when smoke from prescribed burning obscured visibility on highways and on forest roads. In this situation, smoke is an important safety hazard. The consensus of the Air Quality Panel is that local traffic law enforcement agencies should be consulted when such incidents may occur.

AI-3 Air Traffic Hazard

Although interference with air traffic by smoke from prescribed burning is not known to the Air Quality Panel, it is desirable to provide for the possibility. Smoke from wildfires has caused such problems. Advance notification (for emergency procedure planning and for aviation advisories) could be needed by both airport managers and the Federal Aviation Authority.

AI-4 Avoidance of Prolonged Smoldering

When piles of slash include soil, prolonged smoldering may be expected (Cramer 1974, p. F-13). Combustion will occur at a maximum rate when fuel arrangement is sufficiently compact to provide optimum heat exchange between fuel particles while providing for adequate ventilation (Martin and Brackebusch 1974, p. G-6; Cramer 1974, p. F-13). Moist fuels will reduce fire intensity and produce more smoke (Cramer 1974, p. F-11 and F-32).

AI-5 More Complete Combustion from Splitting Stumps

Drying and ignition occur more rapidly as the ratio of surface area to volume increases (Martin and Brackebusch 1974, p. G-5). Therefore, for more complete combustion, large residues such as stumps and rootwads should be broken into smaller pieces. By Air Quality Panel consensus, it is desirable to require splitting of stumps with top diameters over 24 inches.

AI-6 Avoidance of Low Energy Fire

When piles are chunked in, the full-fire stage may be prolonged, reducing the smoke which can be expected from low energy fire (Cramer 1974, p. F-14).

AI-7 Need for Mopup

During the final stage of burning when the fire is of low energy, smoke may accumulate and drift at fire elevation (Cramer 1974, p. F-14).

AI-8 Reason for Larger Piles

Larger piles (or windrows) have less edge-effect, and thus, less incomplete combustion (Cramer 1974, p. F-14). Greater smoke dispersal is achieved by the hottest fire with the strongest convection column (or more efficient "chimney") (Cramer 1974, p. F-16).

AI-9 Flammability and Fuel Moisture

Damp fuels produce more dense smoke (Cramer 1974, p. F-32) and do not carry fire well. By Air Quality Panel consensus, 4-inch diameter (small end) and smaller fuels should ignite and burn readily to meet the 3-inch size specified by Fire Management Panel (see FI-3, p. 184) as desirable to be removed. Tables by Morris (1966) relate fuel moisture stick values to fuel moisture favorable for prescription burning.

AI-10 Smoke Episode Risk as a Basis for Use of Prescribed Fire

The recurrence of fire of natural origin is fairly well established for most northwestern forest types (Martin and Brackebusch 1974, p. G-3; Cramer 1974, p. F-6 to F-8). Fire, then, has played natural roles in the shaping of our forests. These natural functions of fire in unprotected forests include periodically removing dead fuel accumulation on the forest floor, limiting the density of reproduction, providing seed bed, and in some cases, killing all vegetation to start new cycles of growth. In other cases, natural fire destroys only part of the vegetation, including ground cover or overstory timber (either as individual trees or as groups of trees). Forest management imitates these roles by substituting prescribed fire or mechanical treatments that also help to exclude destructive fires. Unfortunately, we have not always been able to completely substitute management practices for the natural roles of fire which are beneficial. It is thus suggested that forest management be extended further through more use of fire by prescription.

Fire control specialists and ecologists recognize that complete fire exclusion has increased the potential for wildfire and smoke (Cramer 1974, p. F-9). Disposal of logging slash is decreasing, particularly in partial cut stands--a cutting practice being extended markedly in some forest areas. This decrease in slash disposal is in part due to air quality concerns, but the net result may be an increase both in destructive fires and in unwanted smoke episodes (Cramer 1974, p. F-7).

Because a reduction in fuels by prescribed fires, under conditions when smoke can be managed, can reduce the potential for conflagrations, this is a favorable trade off--a small amount of smoke under control traded for a future smoke pollution episode (Cramer 1974, p. F-19).

Effectiveness of forest residues management in terms of air quality and fire hazard abatement cannot be fully determined in a short timespan because of variations in seasonal fire load severity resulting from yearly differences in weather (Cramer 1974, p. F-8). An environmentally balanced decisionmaking

aid is needed by which long-term losses, including loss of air quality, can be evaluated (Cramer 1974, p. F-44). But at present we have only the interim rule-of-thumb procedure presented below that is based on:

1. Likelihood of serious wildfire with no residue treatment;

2. Amounts of fuel consumed, hence smoke produced, by

    a. Wildfire in untreated fuel,

    b. Prescribed residue treatment by fire;

3. Susceptibility of the area to

    a. Smoke management,

    b. Wildfire smoke episode.

<u>Rule-of-thumb for Judging Prescribed Fire as a Smoke Episode Prevention Measure</u>

<u>Step 1</u>: Through all columns in the tabulation below, trace the decision path best describing the situation being judged.

<u>Step 2</u>: Calculate the estimated tons of fuel which would be consumed:

a. By the time an uncontrolled fire is controlled, based on expert opinion using preattack or similar planning of strategic locations, expected fire behavior, and knowledge of available suppression forces.

b. By the prescribed burning needed to reduce the likelihood of the uncontrolled fire.

<u>Step 3</u>: Using expert opinion to evaluate fire risk in terms of lightning occurrence, uses, and experience in similar areas, assign an annual percentage of the likelihood of the uncontrolled fire occurring. For example, if six such fires occur annually in 300,000 similar acres, and the area under consideration (determined in Step 2a) is 30,000 acres, then the likelihood

$$P = 6\left(\frac{30{,}000}{300{,}000}\right) = 0.6,$$ or 60 percent chance that an uncontrolled fire will occur.

<u>Step 4</u>: Substitute the above determined values in the following formula,

$$P > \frac{C}{L-C}$$

where: P is the decimal equivalent of the percentage of likelihood of an uncontrolled fire (smoke episode) in Step 3; C is the cost to prevent the occurrence of a wildfire smoke episode, here expressed in tons of fuel which would be burned by prescription in Step 2b; L is the loss if the wildfire smoke episode occurs, expressed in terms of the tons of fuel consumed by wildfire (Step 2a). If the substituted values meet the terms of the formula, benefit to long-term air quality may be included as a basis for deciding to burn.

Considering the known climatology

	If the fire is uncontrolled	If the fire is prescribed	INPUT TO DECISIONS
Given: a type of fire which will produce smoke →	And objectionable smoke would not be likely to affect a smoke sensitive area →		→ Any decision to burn by prescription should not be based on a long-term benefit to air quality.
	Or objectionable smoke would be likely to affect a smoke sensitive area →	And objectionable smoke can readily be kept out of smoke-sensitive areas by routine smoke management. →	→ Any decision to burn by prescription can include a long-term benefit to air quality without further use of this rule-of-thumb.
		Or objectionable smoke would be likely to affect a smoke-sensitive area because of low probability of favorable dispersion weather, excessive indigenous air pollution, proximity to smoke-sensitive area, absence of low emission burning procedure, etc. →	→ Before a long-term air quality benefit is included as a basis for burning by prescription, do steps 2, 3, and 4.

The formula used here is an adaptation of the concept: Before an expenditure is made to prevent a loss, the probability (P) of the event causing the loss must be greater than or equal to the ratio of the prevention cost (C) to the loss (L). Since the fuel consumed in the wildfire smoke episode (L) includes the fuel consumed in the prescribed fire used to prevent the episode (C), in this adaptation C is deducted from L in the ratio. Tons of fuel are used in this rule-of-thumb application due to the difficulty of assigning a meaningful dollar value to the smoke episode.[1/]

AI-11 Strong Convection

The strong, very hot convection column sustains the greatest upward momentum and mixes comparatively little with the ambient air through which it rises (Cramer 1974, p. F-16). Ignition patterns, firing sequence, and timing can be prescribed to produce strong convection.

An exception to prescribing a hot fire and strong convection may be allowed for prescribed underburning conducted when there is a substantial mixing layer and the wind direction is away from any smoke sensitive area.

AI-12 Equipment Exempt From Air Quality Limitations

It has been suggested that permanent injury to human health from the products of forest fuel combustion is not established, but rather, the greatest penalty is in a decrease in visibility (Hall 1972). Forced-air systems, such as those employing the air-curtain type of blower, have been demonstrated to be effective for burning even damp material almost without visible emission (Cramer 1974, p. F-32). By Air Quality Panel consensus, no air quality limitations are deemed necessary for this type of burning.

AI-13 Need for Approved Smoke Management Plan

Any combination of broadcast burning is likely to be a conglomerate of dry, hot-burning and damp, slow-burning fuels. Duff and rotten wood by themselves burn slowly and with considerable smoke (Cramer 1974, p. F-12). Most open burning is to some degree affected by such fuel mixtures as well as by other combustion phenomena and is thus, from an air quality standpoint, a least preferable residue treatment. But open burning is often the only feasible treatment and is also preferable for other reasons. Nevertheless, the smoke from open burning must be managed if air quality is to be maintained. Smoke management is based on variables related to smoke production and dispersion (Cramer 1974, p. F-33). When such smoke management plans are developed and used cooperatively, they can be most effective (Cramer and Graham 1971).

The Air Quality Panel reviewed smoke management plans being followed in the States of Oregon and Washington. From the best of the existing plans and new knowledge available to it, members of the Panel developed a "Model Smoke Management Plan" presented in appendix 2.

1/ For derivation of the formula and a similar application, see Thompson and Brier (1955).

DI--DISEASES GUIDELINES SUPPORTING INFORMATION

DI-1 Reducing Incidence of Root Disease by Limiting Tree Scarring

Logging operations (especially when tracked vehicles or rubber-tired skidders are used) or underburning with high intensity fires can cause wounds on many residual trees. These wounds are ideal entrance courts for several wood-decaying fungi (Hunt and Krueger 1962, Boyce 1961). Wright and Isaac (1956) and Hunt and Krueger (1962) reported that wounds in contact with the ground are more frequently infected than those found farther up the bole of the tree. During logging operations or underburning, most wounding occurs at or near the bases of trees. Wright and Isaac (1956) also showed that the percentage of decay increased with increasing size of scar.

It is therefore desirable to prevent, or at least minimize, wounding of residual trees during logging operations or underburning. It is the consensus of the Diseases Panel that wounding of no more than 20 percent of the residual trees would keep the incidence of root rot diseases to an acceptable level.

DI-2 Reducing Incidence of Root Disease Through Residue Burying Restrictions

Burying of forest residues has been under limited investigation as a disposal alternative for some circumstances. In an examination of residue in pits buried for 2 years in an eastern Oregon ponderosa pine forest area, no evidence of transferred root rot colonization was found.[2/]

Nevertheless, the hazard of certain diseases spreading from already infected residues is believed sufficient to call for formal exclusion of at least diseased material from burying. Three root rot diseases associated with forest residues are of primary concern in the Pacific Northwest.

Armillaria mellea may colonize any wood residue buried or partially buried in the soil. The larger the residue, the more likely are its chances of becoming a source of inoculum. Specialized fungus strands (rhizomorphs) radiate outward in the soil from colonies to infect nearby trees. Younger trees are more susceptible, with mortality seldom occurring in older, more vigorous trees (Nelson and Harvey 1974, p. S-3 and S-4).

Fomes annosus has been observed to spread through roots at a rate of 1 to 6.6 feet per year, depending on species and climate (Johnson and Harvey 1974). Mycelium in colonized roots or residue is capable of infecting healthy conifer roots that contact the infected material, thus spreading infection. As with *A. mellea*, the larger the buried residue, the more likely is it to be an effective source of inoculum (Bega 1963). Although western hemlock is the most

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2/ L. E. Roth. Pathological implications of forest residue disposal by burial and by prescribed underburning. Unpublished manuscript on file at Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, 1973.

vulnerable species in the Pacific Northwest, *F. annosus* has a large host range, attacking both conifers and hardwoods throughout the world. Foresters should consider the possibility of *F. annosus* damage to coniferous forests in any zone (Nelson and Harvey, 1974, p. S-4 and S-5).

Poria weirii is principally a problem root pathogen where Douglas-fir predominates, but it also causes severe damage in some areas of high-elevation mixed conifers. It is the most destructive of the root diseases of the Northwest and has an amazing potential to survive in forest residues. Many cases of survival for 50 or more years have been reported (Nelson and Harvey 1974, p. S-5; Boyce 1961; Childs and Nelson 1971), and one report (Childs 1955) estimated survival for more than a century. Although the potential for colonization of residues by *P. weirii* is open to question, it has been demonstrated to invade Douglas-fir heartwood buried 12 months. Logging debris, other than stumps, is probably of minor importance to continuation of the disease unless it contains *P. weirii* when cut and is buried or partially buried. Infection of roots of healthy trees occurs in much the same way as with *F. annosus* (Nelson and Harvey 1974, p. S-6).

DI-3 Treating Freshly Cut Stumps

Fomes annosus will readily colonize fresh conifer stumps (Russell et al. 1973). If the roots of these stumps are in contact with the roots of living trees, the mycelium may infect the healthy roots. Coating freshly cut stumps with borax is an effective way of preventing this colonization. In a study by Graham (1971), less than 1 percent of pine stumps treated with borax and inoculated with *F. annosus* became infected. In the same study, about 60 percent of untreated stumps became infected when inoculated with *F. annosus*. Russell et al. (1973) also reported from another study that only 3 percent of western hemlock stumps treated with borax became infected as contrasted with 45 percent for untreated stumps. The Diseases Panel concluded that, due to the very high value of developed campgrounds and seed tree orchards, stumps in or near these facilities should be coated with borax to prevent infection of remaining trees.

DI-4 Controlling Dwarf Mistletoe

Dwarf mistletoes are widespread in North America and cause extensive damage to the coniferous forests in the West. This disease will attack trees of all ages, especially seedlings and saplings, causing reductions in yield or mortality (Boyce 1961, Hawksworth and Wiens 1972, Baranyay and Smith 1972).

The best means of control is by cutting or killing all residual trees within and adjacent to an infested tree or stand. Chemicals are not available for direct control of dwarf mistletoe. Although cutting or killing all trees in an infected stand is not always practical nor economical, the disease can be reduced to levels of little growth loss or mortality by proper sanitation measures (Baranyay and Smith 1972).

If dwarf mistletoes are present in living trees remaining after final harvest, the infections may spread to developing regeneration. It takes only 10 or fewer evenly distributed infected trees per acre to cast dwarf mistletoe seeds over the entire acre (Shea and Stewart 1972, Baranyay and Smith 1972). The greatest spread of dwarf mistletoe seed occurs from dwarf mistletoe plants

high above the ground (Hawksworth 1961). If infected trees over 4 feet high were cut or killed, the disease incidence would be minimized to a manageable level.[3]

DI-5 Sanitizing Equipment to Prevent Spread of *Phytophthora lateralis* Root Rot

According to Roth et al. (1972), Port-Orford-cedar is highly susceptible to *Phytophthora lateralis* root rot. The greatest incidence of spread is believed to occur through road construction, logging, or other earth movement operations.

There is no known control of this disease. But, if management decisions require logging or other mechanical disturbance in Port-Orford-cedar stands, two precautions should be followed: (a) Because the disease is readily transmitted by soil clinging to equipment, all such equipment being moved from a contaminated area to a noncontaminated area should be thoroughly cleaned with water under high pressure[3] (Batini and Cameron 1971); (b) infected residue must not be moved to an uninfected stand (Roth et al. 1972).

FI--FIRE MANAGEMENT GUIDELINES SUPPORTING INFORMATION

FI-1 Value-at-Risk

Research and development leading to an expression of value-at-risk truly comparable between different areas and different regions are incomplete. Most land managers have fire plans which incorporate some measure of fire risk, even if totally subjective. Many have fire plans which also reflect resource values. Commonly, these plans are used for assigning priorities and allocating fire management resources.

Because of the absence of a universally accepted method of ranking value-at-risk, or even of arriving at common measures of the separate elements,[4] the Fire

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[3] James Hadfield, USDA Forest Service, Portland, Oregon, personal communication, 1974.

[4] For example, "risk" in some fire planning is based merely on the number of fires occurring for a given period in the planning area. In other fire planning, risk is based on fire occurrence in a composite of similar fuels, land uses, climates, and other factors to avoid a "history of luck" and/or a "history of too limited experience." (The latter composite method is similar to an insurance actuarial base over a large but fairly homogeneous population. A simple adaptation of this composite approach has been suggested for determining the risk of a wildfire smoke episode in the rule-of-thumb presented in Step 3 of AI-10, p. 175.) Similarly, "value" in some fire plans may be only the potential loss of unsalvageable timber and growing stock. In other fire plans, value may include the potential loss of downstream water improvements, lost opportunity for recreation enjoyment, and the cost of suppressing fires. Ways to handle value discounting, fuel rate of spread, ignition capability, and many other variables, all add to the present complexity and divergence of methods for estimating value-at-risk.

Management Panel agreed on the use of three broad classes. Panel members believed these classes could be well understood among land managers of the Pacific Northwest, despite differences in fire planning. This grouping results in a distorted weight being placed on value but does at least in part reflect man-caused fire risk.[5/] The risk of lightning-caused fires is not incorporated.

Although admittedly imperfect, the Panel's list, presented below can serve to suggest appropriate classes for areas where no other method exists for rating value-at-risk.

List of Primary Land Use Categories Grouped by Value-at-Risk Classes[6/]

High value-at-risk	Medium value-at-risk	Low value-at-risk
Commercial development	Scenic area	Noncommercial forest
Recreational areas, heavy and diversified	Winter game range (nonsprouting forage species)	Winter sports areas
Seed orchard	Irrigation (water) areas	Wilderness
Historical area	Industry (water)	Primitive Area
Domestic water	Timber (old growth)	Seed production area
Camp and picnic area	Land suitable for recreational development	Perennial forb range
Endangered species	Barometer watershed	Seed collection area
Rare species habitat	Peripheral species (fauna)	Range meadow
Anadromous fish (a strip shading stream)	Geologic areas	Range conifer, pinion pine, juniper, broad-leaf tree
Water influence zone	Timber (poles)	Sagebrush
Experimental Forest	Timber (second growth)	Natural Area
Brushfield (erodible soil)	Timber (reproduction)	Brushfield (nonpalatable) stable soil
Power (water)	Timber (saplings)	Range grassland
National Recreation Area	Game and nongame (sprouting forage species)	Site class V and VI lands
Congressional classified area	Site class III and IV lands	
Summer home area		
Brushfield (thin soil)		
Fisheries		
Travel influence zone		
Archeological area		
Botanical area		
Site class I and II lands		

5/ See, for example, heavy use by recreation groups under "High value-at-risk" and high use of wilderness by groups under "Low value-at-risk" in the list adopted by the Fire Management Panel. A special reservation is necessary, however, for areas routinely closed to use during periods of high fire danger, which may thus fall in lower classes than indicated. (See also FI-13, p. 196.)

6/ Adapted by Fire Management Panel from "National Fire Planning Instructions," 1972 (unpublished copy on file, USDA Forest Service, Division of Fire Management, Washington, D.C.).

FI-2 Fuel Type Classifications

By Panel consensus, the fuels classification system in use by the Pacific Northwest Region of the Forest Service (USDA Forest Service, Pacific Northwest Region 1968) was selected as a reference from which other agencies and owners with other classification systems could most easily define equivalencies.[7/] The selected system defines each fuel type by four classes, both for rate of spread and for resistance to control:

E - Extreme
H - High
M - Moderate
L - Low

In use, the rate-of-spread rating is expressed first. For example, a fuel type rated as "EM" would be expected to have an extreme rate of spread and moderate resistance to control.

Rate of spread in the selected system is an expression of the perimeter increase for a small fire burning on an "average worst day" in the locality of the rating. Each spread class is five times greater than the next lower class. (An "E" rating would thus be 125 times greater than an "L" rating, 25 times greater than an "M" rating, and 5 times greater than an "H" rating.) From this, it can be seen that weaknesses are to be found in: the absence of any direct allowance for spread due to spot fires (except as snags are illustrated in higher spread rate examples); the absence of any definite allowance for crowning (except as ladder fuels are illustrated in higher spread rate examples); the need for a method of uniformly determining "average worst" as well as the theoretical chance (in using such an average) of an overrating 50 percent of the time and an underrating 50 percent of the time;[8/] the need to subjectively integrate such sensitive variables for the locality of the rating as:

Slope
Exposure to wind
Exposure to insolation
Fuel particle size, texture, and arrangement
Extent of live and dead fuel and seasonal changes therein.

Resistance to control in the selected system is an expression of the amount of work needed to control a unit of fire perimeter. Each resistance to control class is twice as great as the next lower class. (An "E" rating would thus be eight times greater than an "L" rating, four times greater than an "M" rating, and two times greater than an "H" rating.) Weaknesses are to be found in:

7/ Though not referenced as such, the selected fuel classification system has apparently been adapted from the work of Hornby (1936) which is discussed in detail in "Forest Fire Control and Use" (Brown and Davis 1973).

8/ Although difficult to prove and beyond the scope of the present discussions, it must be noted that at least for planning strategic locations for use in controlling conflagrations, fuels must be evaluated in terms of "worst probable" burning conditions.

the subjective determinations of the relative amount of work required, the need to make an additional allowance for travel time and availability of control resources, and the absence of an adjustment for fire intensity as it affects the directness of control action.

Selection of this system by the Fire Management Panel, despite such weaknesses, was due to the existence of a set of photographs for differently rated fuel types in the published system guide (USDA Forest Service, Pacific Northwest Region 1968), and due to the absence of a universally accepted, improved system. The Fire Management Panel felt that in practice, these photographs would serve Northwest land managers better than any other interim method.

FI-3 Consequence of Fuels Under 3 Inches in Diameter

Needles and branches one-fourth inch and less in diameter are the fuels that propagate the main forward spread of fire (Anderson et al. 1966, cited in Martin and Brackebusch 1974, p. G-8). Additionally, studies of slash fires show that 95 percent of fuel particles under 3 inches in diameter are consumed, which influences the energy release rate[9/] (Martin and Brackebusch 1974, p. G-12), a factor which may be important in containing the fire (Martin and Brackebusch 1974, p. G-9). Dry coniferous foliage, in addition to being fine in texture and often arranged to favor flame propagation, may provide more head per unit of measure than other fuels because of a high content of resin (Martin and Brackebusch 1974, p. G-8).

FI-4 Consequence of Larger Fuel Particles

Fuel particles larger than 3 inches in diameter are consumed in part by the passing fire head and have been estimated to be about 30 percent consumed in overall slash fires (Martin and Brackebusch 1974, p. G-12). Although not of "flash" burning character, these fuels still contribute to the total heat and the convective activity of the fire. This can be an advantage in prescription burning when smoke management requires maximum rise for dispersion aloft, but it can be a disadvantage in wildfire suppression because increased radiation and transport of burning embers cause long-distance spotting.

Fire whirls, which cause considerable spotting, are also related to rapid energy release. The larger fuels also smolder long after the fire is past, threaten to cause breakouts, and require extensive mopup. With time, they become punky and ignite easily (support glowing combustion) when dry (Martin and Brackebusch 1974, p. G-7). These are also the fuels which result in extreme ratings for the work (resistance to control) of controlling the fire. Because they produce intense fire and are difficult to cut and move, these large fuels where sufficient are a hindrance to initial attack so that small fires can rapidly escape to become potential conflagrations. For these reasons, reduction of overall fuel loading is advocated (Martin and Brackebusch 1974, p. G-9).

[9/] Energy release rate, assuming a relatively constant combustion efficiency, is dependent upon the rate of spread (in area) of the fire head times the amount of fuel consumed in the head.

FI-5 Use of "MM" Fuel Rating as a Benchmark

The medium rate of spread and medium resistance to control fuel rating (see FI-2, p. 183) was selected as a benchmark fuel rating by Fire Management Panel consensus. This benchmark is the rating value the Fire Management Panel believed should not be exceeded in several specified circumstances; it was chosen for the following characteristics of the MM[10/] fuel type:

Rate of spread (see FI-3, p. 184)

- Available very fine fuels such as needles and flammable grass are low in quantity and are generally discontinuous.
- Available fuels larger than very fine, but under 3 inches in diameter, are relatively low in quantity and usually scattered.
- Ladder fuels and fuels with spotting potential are generally absent.

Resistance to control (see FI-4, p. 184)

- Control lines can usually be located to avoid larger logs.
- Work required to install control lines is commonly within the capability of most initial attack suppression resources.

FI-6 Land Stewardship

Most land managers strive to bring about improvement in resource conditions or at least to avoid degradation. The Public Land Management Decisions Panel applied this philosophy of land stewardship in their judgment that a desirable and attainable guideline statement should, as a minimum requirement, permit no activity to increase the hazard over the preactivity fuel hazard ratings. Past experience has shown that disputes develop over fuel quantity and arrangement necessary to meet a particular rating and over whether a particular residue component existed before, or as a result of, the activity. Critical differences in microclimatic factors, such as exposure to wind and sunlight,[11/] also need to

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10/ The MM fuel rating should not be regarded as an optimum for all fire management situations. For example, an MM fuel will not always be satisfactory where preattack installations require fuel modification (see FI-9, p. 187, and FI-10, p. 189). Further, a higher percentage of crown fires has been reported to develop in medium rate of spread fuels than in any other class (Barrows 1951a). We noted an apparent discrepancy in the photograph depicting an MM type on page 23 in "Guide for Fuel Type Identification" (USDA Forest Service, Pacific Northwest Region, 1968). Unless the influence of "average worst" for the locality of this photograph permitted more fuel as an atypical situation, we would rate this as "HM." See also FI-12 (p. 195) regarding need for areawide treatment and reference to fuel loadings in the Sundance Fire.

11/ The effects of insolation upon fire behavior are not yet sufficiently well known to express as results of research. Some limited experiments and observations indicate an effect on fuel moisture and on the energy needed to propagate fire spread.

be recognized in the comparative fire hazard rating. Residue components need not be considered in terms of prior or subsequent existence, but rather in terms of their contribution to a desired fuel hazard rating.

FI-7 Reduction of Fuel Hazard, Prescribed Use of Fire, and Fire Under Surveillance in Areas Formally Designated Under the Wilderness Act

Both the Fire Management Panel and the Public Lands Management Decisions Panel considered the need for fuel hazard reduction and the potentials for the use of prescribed fire, or of permitting fires to burn under surveillance, in areas formally designated under the Wilderness Act. Only guideline statements 2.306 and 2.308 through 2.310 are directed toward Wilderness (along with other land classes) as a result of the Fire Management Panel process. Although none of these deal with permitting fire to burn under surveillance, a near-consensus of the Public Land Management Decisions Panel gave support to case-by-case application. Despite legal and policy implications, as well as the apparent need for further analyses, this support warrants being reported as a reflection of current administrative deliberations and of related research in progress.[12/]

For Wilderness, methods of residues management other than those identified above were not undertaken by the Fire Management Panel due to current interpretations of the Wilderness Act. Discussions among panelists did, however, indicate a possible need to liberalize authority for limited use of prescribed fire, both for fuel hazard reduction and for maintenance of certain species. Legal authority may also be needed for use of prescribed fire on limited fuel breaks, at least along Wilderness boundaries in strategic locations where the objective would be to halt conflagrations originating either in or outside Wilderness.

FI-8 Snags

Fire Management panelists agreed on the definition of "snag" (see "Glossary"), as well as on the need to treat snags for fire management purposes. But present differences in laws relating to snags prevented further agreement on minimum size of snags for treatment or on the exemption from treatment of certain snags for wildlife habitat. For this reason, the Fire Management Panel elected to call for treatment of only the snags associated with activity-produced residues, leaving further specification to law and to individual owners and agencies. The following discussion supporting snag treatment is for readers who may wish to pursue an acceptable further specification. Support for the associated wildlife exemption will be found under TE-15, p. 221, and TE-16, p. 222.

[12/] The reader is referred to these additional references on current knowledge, policy, and research on prescribed fire and fire under surveillance in formally designated Wilderness Areas and related areas: USDA Forest Service Manual 2324.24, "Use of Fire," Amendment No. 35, May 1969; USDA Forest Service Manual 5130.3.5, "Policy--deviation," Manual Amendment No. 38, May 1972; USDA Forest Service, "Fire Policy Meeting Report Recommendation No. 1," May 12-14, 1971; Intermountain Fire Research Council (1970); Slaughter et al. (1971); Heinselmann and Wright (1973).

Snags are regarded as one of the most important fuels influencing fire starts and fire control. Their relatively low moisture content and the ease with which glowing combustion can be initiated after deterioration make them a ready fuel for ignition. Radiant heat and firebrands falling on punky snags have accounted for many new starts of fires outside intended control perimeters. Lightning strikes in snags and in snag-topped green timber frequently become sources of wildfires even if precipitation accompanies the thunderstorm because of the snag's ability to ignite and then to hold the fire in hollow portions while the surrounding forest area dries out (Barrows 1951b; Brown and Davis 1973; Martin and Brackebusch 1974, p. G-8). Fire management personnel believe that numbers of lightning fires are reduced in areas where sanitation salvage has removed snags and snag-topped trees in the southwestern National Forests,[13/] and studies of 12,000 fires in the northern Rocky Mountains are reported to have shown that over 34 percent of such fires started in snags (Barrows 1951a, 1951b).

Fire behavior is also importantly influenced by snags since they tend to serve as aerial platforms from which burning embers are launched on trajectories including long distance transport during strong winds or convective activity. Shaggy barked snags are particularly notorious for propagation of burning embers (Barrows 1951a).

Short snags and stubs in a renewing forest will usually be overtopped by the crown canopy more quickly than tall snags. Under the canopy they will be in a damper microclimate and thus contain more moisture, decay more rapidly, and be less likely to ignite and scatter firebrands than tall snags (Brown and Davis 1973). This is, no doubt, part of the basis for the 20-foot height used in the generally accepted snag definition. Height can also be part of the basis for further specification, where crown closure and regrowth characteristics of different forest types should be reflected. The proximity of snags to strategic fire control locations--for control lines, fuel breaks, etc.--might be the basis of an additional guideline for snag removal. Likely trajectory of firebrands, susceptibility of fuels to ignition, and kind of strategic use would be considered.

FI-9 Preattack Planning

The term "preattack" and the concept it represents were adopted for these guidelines by Fire Management Panel consensus. Also known among some foresters as "prefire planning," preattack planning covered in this discussion is only a part of the whole concept, which includes installation and maintenance phases as well.[14/] It is a system of planning in advance of fire suppression and is done to accomplish two primary objectives: eliminate time lost in scouting and planning at the time of attack and provide a systematic basis for determining the what and where of installed fire control facilities.[15/]

[13/] Hugh R. McLean, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, personal conversation, 1974.

[14/] For discussion of installation and maintenance phases, see FI-10 (p. 189).

[15/] For preattack priorities, see "Fuel Treatment Priorities," p. 192, under FI-10.

Preattack planning has grown from similar work done in many areas of the Nation since forest fire protection first began. The most recent developmental work was done on the southern California National Forests (Grace 1951). These procedures have been incorporated in Forest Service regional guides (USDA Forest Service 1959; USDA Forest Service, Southwest Region [n.d.]; USDA Forest Service 1972) as well as in a Forest Service national handbook (USDA Forest Service 1970). Although the regional guides are localized, they still conform to a standardized system which closely resembles the planning pioneered in southern California. Most notable in the extension of the preattack concept from chaparral to timbered areas and to shaded fuel breaks is work done in the 1960's on the Duckwall Unit of the Stanislaus National Forest in California's central Sierras (Green and Schimke 1971).

Preattack planning in the Pacific Northwest is a major advance in forest residue management, but the Fire Management Panel recognizes that some of the procedural details[16/] and intensive application may not be appropriate for all public and private lands. The basic thrust is at least to plan to break up large continuous problem areas so as to accommodate preattack installations or objectives (Martin and Brackebusch 1974, p. G-22) (see FI-10, p. 189).

The following outline for preattack planning, adapted from Forest Service directives and guides, is offered as a standardized approach.[17/]

PREATTACK PLANNING PROCEDURE

Step 1: Identify preattack blocks (20,000-50,000 acres within well-defined terrain features).

Step 2: From topographic maps and aerial photos, identify strategic locations for firelines, fuel breaks, and other fire control facilities.

Step 3: Consider coordination with other land uses. Will proposed installations, either on a going fire or preinstalled, be acceptable?

Step 4: Complete field inventory and identify all final choices for strategic location of fire control installations; assemble as block plans.

Step 5: Obtain any needed approvals for preattack plan, including final coordination with other land uses.

Step 6: Provide for updating plans and sending copies to dispatchers and fire suppression personnel; and give information to personnel in activities such as timber management and engineering who may install priority preattack facilities.

16/ See, for example, inclusion of the "TRI System" (Robertson 1969) in the Pacific Northwest Region preattack guide (USDA Forest Service 1972).

17/ A guidebook presenting an adapted but uniform system of preattack planning for private lands and some public lands has been identified as a high-priority developmental need.

FI-10 Installation and Maintenance of Fuel Breaks and Related Preattack Facilities

The concept of preattack adopted by Fire Management Panel consensus embodies installation and maintenance phases discussed here, as well as the planning phase discussed in FI-9, p. 187. Fuel breaks have been emphasized because they break up continuous problem fuel areas by modifying the fuels in strategic locations (Martin and Brackebusch 1974, p. G-23).

Other facilities (such as helispots used in manning fuel breaks, and water sources in support of forces on fuel breaks) are no less important. Unmanned, or manned but poorly supported, fuel breaks are only occasionally effective in stopping fires. Fuel breaks are not fire barriers! The fuel break is intended only to provide safe access and a place from which to make either direct or indirect attack.

Like preattack planning, fuel break installation and maintenance have evolved from work done in many areas of the Nation; most recently fuel breaks have been installed in the southern California National Forests as part of their preattack system. Firebreaks and fire lanes installed there during the CCC (Civilian Conservation Corps) era have been an accepted part of the southern California scene. But firebreaks are not the same thing as fuel breaks. Firebreaks are devoid of vegetation, but only partial removal and modification of fuel arrangement are the rule in fuel breaks. Fuel breaks in timber often go unnoticed.

The following subsections are further support for fuel break-related guidelines originated by the Fire Management Panel.

Successes and failures of fuel breaks.--Only a few success stories have been published for fuel breaks (for example, Murphy and Murphy 1965). Reports of individual successes and failures, mostly communicated by word of mouth, have resulted in mixed opinions as to their worth. In an attempt to clear away confusion, we have drawn on two summaries of known encounters between fuel breaks and fires.[18/] [19/] These summaries were supplemented with individual documents supplied by the National Forests in California. See appendix 3 for this information.[20/] From our analysis, we conclude that success is most likely when fuel breaks are properly installed and maintained and adequately manned, and manning is adequately supported.

[18/] James W. Jay. A look at fuel breaks. 60 p., illus. Unpublished report on file, Division of Fire Management, USDA Forest Service, Washington, D.C. [n.d.].

[19/] Lisle R. Green, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Forest Fire Laboratory, Riverside, Calif., personal conversation, 1973.

[20/] We recognize a need for more detailed study than could be afforded for this analysis and offer their results only as the currently best available information.

Prudent suppression tactics are also important:

a. A control line is established.

b. Spot fires are detected and contained rapidly.

c. Backfiring or firing out operations are initiated at the right time.

d. Control of the flanks of fires is accomplished (some very successful encounters became failures due to subsequent outflanking).

The likelihood of failures increases when the above elements are not met and/or when very high winds and erratic fire behavior or fire storms are experienced. Obviously, if a fire starts immediately adjacent to a fuel break, time is critical in meeting the above elements. Good access is thus a key consideration.

Occasional successes have been reported even for unmanned fuel breaks. We consider these the exception rather than the rule. In those cases, fire behavior was moderate and/or the encounter was along a flank, and either the ground fuel along the fuel break had not yet become established or a maintained firebreak or other barrier (such as green grass or a road) existed within the fuel break.

Some concern has been expressed that dry grass on lateral fuel breaks will serve as a "fuse" to spread fire more rapidly upslope. Although this is a real possibility, some fires would likely spread up these slopes regardless, even if at slower rates. Because dry grass ignites readily and access is provided, there is also a related possibility for an increase in man-caused fires which could make rapid initial runs along fuel breaks. For example, if trail bikes are used on fuel breaks, risk of ignitions from faulty exhaust systems is a definite possibility. However, fire prevention measures can be taken which will make the fire risk low enough to offset the advantages of an installed fuel break network.

Impact of installations.--The two potential impacts of most concern among land managers have been on esthetics and on timber production. Land managers have feared that fuel breaks would be the same as the firebreaks they have seen in chaparral. This would not only make an unwanted vegetative contrast, it would take land out of production. But in chaparral, feathered irregular edges and clumps of brush left in fuel breaks produced an appearance more like naturally grassy open ridges when carefully done. In timber, a shaded fuel break can be made inconspicuous by careful thinning, and by feathering edges and leaving clumps of understory.[21/]

Timber production on fuel breaks is affected by the extent to which trees are thinned, by the care with which equipment is used, and the intensity of prescription burning practiced. In a case study of three representative fuel breaks in California, investigators concluded that rather than a subtractive effect, the present net worth of benefits to timber production (through increased growth on the fuel break) ranged from $1 to $10 per acre of fuel break (Grah and Long 1971).

21/ See guideline statement 1.520 in chapter III for a specified application of landscape management to fuel breaks.

Economic Analysis

Two studies--one by Davis,[22/] the other by Murphy[23/]--in 1965 seemed to be in conflict over the economics of fuel break construction. Davis used decision games and simulation to estimate fuel break effectiveness in a California Division of Forestry District. These estimates were then used to determine reductions in acres burned annually, to indicate effectiveness of both fuel breaks and additional suppression forces. Costs for reducing average annual acreage burned were believed to exceed all market and nonmarket losses due to wildfire, and the conclusion was reached:

> ...within the limits of assumptions used in this analysis, development of extensive fuelbreak systems or making substantial physical additions of conventional fire suppression forces to the current level for protecting Zones I and II wildlands in District III of the California Division of Forestry does not appear economically justified.

This conclusion, taken by itself, leads to the confusion. This is unfortunate because, in further discussion of the implications of his analysis, the author concluded:

> Increases in funds for wildfire protection by the California Division of Forestry in District III...would probably be more effective in reducing the acreage burned by major fires if directed toward *selective* (italics ours[24/]) fuelbreak construction and to fire prevention effort rather than to direct suppression forces.

Murphy[23/] used costs collected during the Duckwall Conflagration Control Project on the Stanislaus National Forest. These costs were synthesized with the value of fire damage averted, and the marginal rate of substitution of fuel breaks for fire suppression was found. This finding was integrated with the least-cost-plus-damage method of analysis. Although the author concluded costs would be high, he stated: "Conflagration control through fuel breaks combined with a complementary fire suppression organization is economically justified on the Duckwall Unit."

When we recognize that the two studies are for two different situations, with different values-at-risk and different existing fire suppression resources, they actually may be viewed as complementary. Both conclude that fuel breaks to a certain level are economically justified. Both recognize that a certain level of suppression resources is necessary to use the fuel breaks, even though one study implies a need for increased suppression force expenditure and the other a reduction.

22/ Lawrence S. Davis. The economics of wildfire protection with emphasis on fuel break systems. Doctoral dissertation, University of California, Berkeley, 166 p., illus., 1965.

23/ James L. Murphy. An analysis of the economic efficiency of an experiment in conflagration control on the Stanislaus National Forest, California. Ph.D. thesis, University of Michigan, Ann Arbor, 258 p., illus., 1965.

24/ See further discussions of economics of selecting highest priority locations under "Fuel Treatment Priorities," p. 192.

Fuel Treatment Priorities

Work has been done to refine the process for assigning priorities of fuel treatment and allocating budgets for fire management. The more sophisticated work in decision modeling was done for chaparral fuels under grant from the Forest Service to the Stanford Research Institute. The principal conclusion reported from this study[25/] is that a program of fuel modification seems economically justified for the pilot area studied.[26/] Less conclusive results have been obtained for the choice between an extensive system of fuel breaks and one of expanded fuel breaks ranging up to a mile wide.

Two methods for aiding the assignment of priorities of fuel treatment or determining the optimum density of fuel breaks in the Pacific Northwest are under development.[27/] [28/] Such decision-aiding methods will be most helpful, but in this document we accept the expert opinion of the Fire Management Panel's judgment that work on fuel breaks should be undertaken now. To begin with, highest priority locations for primary fuel breaks can be selected from local preattack planning and fire planning information based on fire risk and values. A preliminary list of priority locations for ultimate widening of fuel breaks to become areawide treatments can be developed from this same knowledge. Although decision-aiding models are likely to be completed before more difficult priority decisions need be made, this skeleton list of suggested priorities may be used as a start:

Priority 1. Standard fuel breaks around and through high value, high hazard, intensive use areas (e.g., resorts, camps, communities).

Priority 2. Standard fuel break segments on ridges above high risk areas.

25/ J. Michael Harrison, D. Warner North, and Carl-Axel S. Staël von Holstein. Decision analysis of wildland fire protection: a pilot study. 196 p. Unpublished manuscript on file, Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif., 1973.

26/ Matilija Creek and San Antonio Creek Drainages, Los Padres National Forest.

27/ Stewart G. Pickford. Work plan--analysis of fuel treatment alternatives. Unpublished manuscript on file, Pacific Northwest Forest and Range Experiment Station, Portland, Oreg., 5 p., 1974.

28/ Gary W. Lyon. Economic analysis of fuelbreaks. Unpublished manuscript on file, Pacific Northwest Forest and Range Experiment Station, Portland, Oreg., 29 p., 1974. Lyon, though concluding that fire damage is a parameter with weak input data, indicates that fuel breaks would be economically justified for the Snoqualmie National Forest. In this study, "net savings" are calculated for each proposed fuel break, making priority decisions possible. Weaknesses relative to fire damage inputs would be overcome in part if methods proposed by Pickford (see footnote 27) are successful. Pickford's work is directed toward an adaptation to the Pacific Northwest of an economic analysis method being used for fuel break decisions in the California Region of the Forest Service.

Priority 3. Standard primary fuel breaks along major ridges or other breaks in topography (e.g., block boundaries).

Priority 4. Standard fuel breaks on lateral ridges where outflanking of primary breaks is most likely.

Priority 5. Concurrent expansion of lateral and standard fuel break network, and areawide prescription burning (in forest types where suited).[29/]

Construction and Maintenance Standards

The following statements and quoted excerpts (from Green and Schimke 1971)[30/] represent the best known standards for fuel break construction and maintenance in the Pacific Northwest, as visualized by the Fire Management Panel.

Width.--Widths of fuel breaks are to be based on an estimate of "the distance from the flame front necessary to prevent serious burns from radiated heat and direct ignition from radiation" from intense fires in extreme fire danger. To this estimated distance must be added a margin for safety as well as the distance needed for varying widths in meeting landscape management requirements.[31/] Widths will vary with the sharpness of ridgetops, the nearness to critical saddles, the incorporation of safety islands, and with the steepness of slopes below slope-crossing roads (when roads are selected as the best available intermediate strategic location). The following widths have been suggested for the Sierra-Nevada mixed conifer type and are being followed in the Pacific Northwest:

...*Knife-edge ridges*--On slopes of of 50 percent or steeper, width should be at least 3 chains, slope distance.

Ridges where one slope is steep (50 percent) and one moderate (20 percent)--These will normally be marked to a fuel-break width of 4 chains, slope distance.

Loaf-shaped ridges--Two slopes of less than 20 percent will be marked for fuel-break treatment to a width of 3 to 5 chains, slope distance.

Valleys or flat areas--Where the ground is level or nearly level and the stand is dense (150 or more trees per acre), the fuel-break should be 5 chains wide. On areas with a less dense stand or when the stand does not extend too great a distance, the thinning should be done to a width of 3 to 4 chains. Outer edges of timber fuel-breaks should be thinned more severely than the center.

29/ See also FI-12 (p. 195) on need for areawide treatments.

30/ Readers are urged to use Green and Schimke's (1971) guides and/or the preattack guide (USDA Forest Service 1972) for actual applications.

31/ See guideline statement 1.520 in chapter III on landscape management required for fuel breaks.

Canyons or ravines--If canyon walls are steep, spotting and radiation across the narrow canyon bottom are hazards. Canyons are not the most desirable sites for fuel-breaks. Consequently, they require more clearing and thinning than do ridgetop sites....

Treatment.--

...*General*--Remove all merchantable high risk, spike-top, damaged, bug infested, and catfaced trees.

Overstory--Remove enough of the remaining merchantable trees to achieve a spacing that will result in a shaded fuel-break of sound, thrifty trees. This will normally entail removing only those overstory trees which have interlacing crowns.

Understory--Thin merchantable understory trees to a minimum spacing of 20 feet or to a spacing of not less than 6 feet between crowns.

Unmerchantable trees--Unmerchantable material (poles, saplings, other material) in the fuel-break should be thinned after logging to a spacing of 6 feet between crowns.

Pruning--Prune crop trees according to..."established..." guidelines. All other "leave" trees must be pruned to a height of at least 10 feet, but not to exceed 50 percent of length of green crown.

Hazard reduction--All slash, brush, and other debris must be disposed of by burning, burying, or chipping. Machine piling, because of lower over-all costs, is recommended where damage to the residual stand can be avoided.

Maintenance.--

...If fuel-breaks are to serve their purpose they must be maintained. The ground cover must be kept to low volume. A ground cover is necessary to stabilize the soil and restrict growth of unwanted woody vegetation.

The aim in maintaining a low-volume ground cover is so that when it is ignited, it will burn with a low total heat output near the control line within a fuel-break. This aim assumes that the cover on a fuel-break will be flammable and that it will burn readily during critical fire periods.

A dry weight of 2 tons per acre has been arbitrarily set as a maximum volume of ground cover desired on a fuel-break. A cover of grass...or pine needles will be less than this volume on most sites in most years....

...Low intensity prescribed burning in tests on the Stanislaus National Forest, central California, has proved its value for maintaining a low level of fuels at low cost (Schimke and Green 1970). The use of this technique should be seriously considered for fuel-break maintenance....

FI-11 Prescribed Fire as a Preferred Treatment for Specified Areas

There is evidence that in the past fire has periodically been a natural element in the ecosystems of such timber species as Douglas-fir, lodgepole pine, ponderosa pine, and western larch (Intermountain Fire Research Council 1970, Franklin and Dyrness 1973). Certain types of fire are believed to be beneficial to these ecosystems (Intermountain Fire Research Council 1970). This led the Fire Management Panel to recommend prescribed fire as the preferred treatment for specified Forest Residue Type Areas.[32/] In calling for use of burning prescriptions, the Fire Management Panel recognized dependence on an improving art in a subject area where further research and development are greatly needed. While research and development[33/] are being conducted in both the Douglas-fir and ponderosa pine forest types of the Pacific Northwest, prescriptions may be drawn from two sources developed outside this geographic area (Pierovich et al. 1968, Schimke and Green 1970).

FI-12 The Need for Areawide Treatment

The need to treat fuels on an areawide basis is apparent to the initial attack fireman trying to hold a fire to small size in fuels which defy rapid handwork and/or are burning with intensities which are not readily quenched by ground or airtanker attack and continue to produce burning embers. Numerous individual fire reports attest to the importance of fuel at or near the point of fire origin. Brown and Davis (1973) point out that one or two highly trained men with handtools can control most fires of one-fourth acre or less but that, in some fuels and under some burning conditions, even a fire this size can overwhelm hand methods.

Preference for areawide treatment is more dramatically demonstrated by conflagrations in which long distance spotting and erratic behavior make it necessary to take flanking action and to depend upon indirect attack. The 1967 Sundance Fire in Idaho is one such fire which has been documented and studied. Anderson (1968) concludes that the spectacular run of this fire appears to have been a result of a combination of dry fuels from a sustained drought, low humidities for over 72 hours, increasing winds sustained over a period of 9 hours, and a 4-mile active front. He reports an advance of 16 miles in 9 hours, spot fires 10 to 12 miles northeast of the point of origin, a rate of spread of 6 miles per hour during the peak run, with a maximum energy release of 474 x 10^6 Btu/s and a maximum fire intensity of 22,500 Btu/s-ft of fire edge. Average fuel loading calculated for the fire area as a whole was divided into three levels: ground litter, brush, and crown material, and was reported by Anderson (1968) as 2.04, 2.7, and 20 tons per acre, respectively.

32/ See chapter II for discussion of forest residue types and key to guideline statements. See SI-6, p. 213, for the further recommendation of the Silviculture Panel on use of prescribed fire.

33/ A priority research and development job is formulation of prescription criteria for protecting specified depths of the duff layer (see SO-11, p. 216).

FI-13 Fire Closures

Federal, State, and local laws and regulations provide for "limited" and "full" closures of forest land to entry during periods of high fire danger. Limited closures may be for certain classes of fire risk or may simply close the area to entry unless certain fire prevention measures (such as the required "shovel, axe, and bucket" for forest visitors or the "hoot owl" schedule for loggers) are taken. Full closures usually close areas away from main traveled routes and away from places of habitation to all entry except by permit (such as for residents). Fire danger used for closures is usually weather dependent but may be declared automatically by dates with the approach of a fire season, and may last for the entire fire season regardless of changes in weather when fuel hazard (as a part of fire danger rating) is high.

Costs and difficulty of enforcing closures sometimes combine with a desire to leave the area open for use, especially on public lands, to the extent that decisions to effect closures are put off in the hope that the weather will change. On the other hand, some private lands remain closed to public entry for extended periods as a prerogative of private ownership in keeping with State and local laws or regulations.

Although literature on studies of fire closure effectiveness is scant, it seems reasonable to include the following in local evaluations of closures as an alternative, or as a supplement, to fuel hazard reduction:

a. Will other management goals be met (e.g., silviculture, providing open space)?

b. Can the closure be effectively enforced without undue costs and without adverse public reaction?

c. Are man-caused fires a problem and will lightning fires negate the results of preventing man-caused fires?

FI-14 Fire Management Through Cooperation

Concern about damage to forests from fire has been linked to the evolution of a forest policy in this country since colonial times. Kinney (1917) began his text on the development of forest law in America with reference to the first ordinance regarding the firing of woods in Plymouth Colony in Massachusetts. He also cited the Massachusetts Act of January 1743, which recognized the damage caused by fire to young tree growth and to the soil, as well as a North Carolina Act of 1777 which carried penalties for unlawful firing of the woods. The first nonstructural fire regulation in Alta California is credited (Clar 1959) to Spanish Governor Jose Joaquin de Arrillaga, whose proclamation of May 31, 1793, addressed itself to the Indian practice of setting fire to pastureland. Use of fire, control of fire, and abatement of fire hazards continue to be controversial in forestry circles throughout the country. Controversy is woven into the history of forestry cooperation as it grew from such Federal regulatory legislation as the Snell Bill introduced in Congress in 1920. Dana (1956) calls the Clarke-McNary Act of 1924 the lineal descendant of the original Snell Bill; he points out its notable omission of any reference to public regulation of timber cutting, a matter of great controversy at the time. Among other provisions of the Clarke-McNary Act was an authorization for the Secretary of Agriculture to cooperate in forest fire control with States. This provision along with others has done much to quiet the pressure for Federal regulation.

It has enabled the States to work with local forestry associations in writing forest practice acts that have been received favorably in the West where there is a strong belief in the doctrine of natural rights. This doctrine has been codified by the U.S. Constitution. It has been used in our highest courts to protect private ownership against public regulation regardless of new constitutional interpretations. The Private Lands Management Decisions Panel recognizes a pride among these owners in their self-regulating forest practice rules and related State legislation (Oregon State Legislature 1971, Washington State Legislature 1974). The consensus of the Fire Management Panel is that individual owners and appropriate local protection organizations should work together to determine treatment criteria for each area instead of attempting to set forth specifications in law which may not be applicable or desirable in all instances.

As an example of the working practice acts, the following quotation is excerpted from the general rules developed by the Oregon State Department of Forestry (1974) through its forest practices committees of private owners:

> 24-301 MAINTENANCE OF PRODUCTIVITY AND RELATED VALUES. Operations on forest land shall be planned and conducted in a manner which will provide adequate consideration to treatment of slashing to protect residual stands of timber and reproduction, to optimize conditions for regeneration of forest tree species, to maintain productivity of forest land, and to maintain air and water quality and fish and wildlife habitat.
>
> (1) Reduce the volume of debris as much as practicable by such methods as:
>
> (a) Well planned and supervised felling and bucking practices to minimize breakage.
> (b) Increased utilization of wood fibre including but not limited to salvaging, pre-logging and re-logging when a market exists.
> (c) Stage cutting where applicable, with successive cuts delayed until slashing created by previous operations is reduced.
>
> (2) In those areas where slash treatment is necessary for protection or regeneration, the following methods may be used:
>
> (a) Scattering of slash accumulations;
> (b) Piling or windrowing of slash;
> (c) Mechanized chopping or compaction of slashing;
> (d) Controlled burning;
> (e) Provisions for additional protection from fire during the period of increased hazard. Protect fish habitat when establishing water sources....

IN--INSECTS GUIDELINES SUPPORTING INFORMATION

IN-1 Preventing Expansions of Douglas-fir Beetle Epidemics

Douglas-fir residue will attract and concentrate the Douglas-fir beetle in the vicinity of green trees (Johnson and Pettinger 1961) and may cause population increases of epidemic proportions (Furniss and Orr 1970). Greeley et al. (1953) reported that in 1951-52 about 8.9 billion board feet of timber was lost to windthrow, plus about 1 billion more due to beetle attack in 1951. An additional 3 billion board feet of green timber was killed by beetle emergence from the windthrown and beetle-killed timber (Johnson 1960a).

Shaded residue poses a greater insect hazard than does residue exposed to direct sunlight (Johnson et al. 1961, Johnson 1960b). Johnson (1960a) reported that high and low temperatures have an adverse effect on beetle broods, causing high mortality rates. In fact, Johnson et al. (1961) found that shaded residue is about twice as attractive to attacking beetles and six times as productive of new beetles as exposed material. Therefore, higher priority should be given to treating shaded and partially shaded residue than to residue found in direct sunlight.

Work by Johnson and Pettinger (1961) showed that intensity of attack decreased with distance from infested trees or logs. The consensus of the Insects Panel is that moving the residue at least 35 feet from living trees will give adequate protection to the stand.

Removal of residue and infested trees is the best means of reducing beetle populations. Ideally, removal or treatment should take place promptly after the residue is created or trees are attacked. If this is not possible, the work should be completed before the beetles emerge, usually within 12 months.

IN-2 Preventing Expansions of Engelmann Spruce Bark Beetle Epidemics

Buildup of spruce beetle populations in Engelmann spruce residues is a major factor contributing to severe tree destruction (Schmid and Beckwith 1972; Mitchell and Sartwell 1974, p. R-5). Broods of this insect may take 1 or 2 years for a complete cycle (Massey and Wygant 1954). The consensus of the Insects Panel is that, for best control of this beetle, infested stemwood residues should be removed from the area within 1 year of infestation to prevent further buildup and outbreak.

IN-3 Providing Future Protection from the Balsam Woolly Aphid

The balsam woolly aphid has caused extensive damage and mortality in true fir stands in the Western United States (Doerksen and Mitchell 1965, Johnson and Wright 1957). Pacific silver fir found below 3,000-foot elevation (Mitchell and Sartwell 1974, p. R-9) and subalpine fir growing above 3,000-foot elevation (Mitchell 1966) infested by the aphid seldom develop to merchantable size. The infested trees are also a source of infestation for subsequent reproduction.

The only effective treatment known is to remove infested Pacific silver fir and return the site to an earlier successional stage (Mitchell and Sartwell 1974, p. R-10). The consensus of the Insects Panel is that removal or destruction of infested Pacific silver and subalpine fir trees would adequately protect remaining stands.

IN-4 Preventing Epidemics of Mountain Pine Beetle in Sugar Pine

Population buildup of mountain pine beetle in recently windthrown sugar pine is a major factor contributing to tree killing (Miller 1928). Normally, losses are very light and most of the damage has been endemic with outbreaks usually short-lived. However, a sudden beetle buildup and increased mortality of mature and overmature sugar pine trees in 1964 were attributed to the 1962 October windstorm. The damaged trees evidently acted as the breeding ground for buildup of the beetle epidemic (Dolph 1970).

The consensus of the Insects Panel is that the best line of defense is removal of accessible windthrown trees within 1 year of blowdown.

IN-5 Preventing Mountain Pine Beetle Epidemics in Lodgepole Pine

The mountain pine beetle is the most serious insect enemy of lodgepole pine and can cause severe damage over extensive areas (Fowells 1965). Lodgepole pine becomes most susceptible to mountain pine beetle attacks at about age 80. Keeping beetle outbreaks to a minimum is best accomplished by maintaining a young, healthy, and vigorous stand (Dolph 1970).

The consensus of the Insects Panel is that the best method for maintaining a young and vigorous stand is removal of all infested trees as well as all non-infested merchantable trees in the area of infestations.

IN-6 Preventing Mountain Pine Beetle Epidemics in Ponderosa Pine

Old-growth ponderosa pine stands rarely experience outbreaks of mountain pine beetles. However, beetle populations have greatly increased and become widespread with conversion of old-growth stands to second-growth management (Sartwell 1971).

Sartwell (1971) stated that beetle outbreaks occurred on about 100,000 acres annually during the 10 years prior to 1971. He also said that this problem will become more extensive as more timbered land is harvested.

The attacked young, second-growth stands were usually even aged, densely stocked, and stagnated. This combination reduced tree vigor making these stands susceptible to beetle outbreaks when the trees grew into pole-size classes (Dolph 1970, Sartwell 1971).

The best direct method for controlling mountain pine beetle outbreaks is by increasing stand vigor through precommercial and commercial thinnings. This produces healthy and fast-growing trees which are more resistant to beetle outbreaks (Dolph 1970).

IN-7 Preventing Damage From Pine Engraver Beetle to Uncut Timber

Removal of fresh residue will reduce pine engraver beetle aggregation, thus decreasing risk to standing trees. Where complete disposal is not practical or economical, the residue should be scattered or piled in openings away from the standing trees (Sartwell et al. 1971; Mitchell and Sartwell 1974, p. R-8).

IN-8 Preventing Loss from Pine Engraver Beetle in Ponderosa Pine Thinning Areas

The pine engraver beetle is mainly a pest of ponderosa pine. Although in most years it is not important as a tree killer, young trees and the tops of older ones are the main targets of this beetle (Metcalf and Flint 1962).

Mortality of leave trees after precommercial thinning occurs predominantly in stands thinned during spring and summer (Sartwell et al. 1971, Sartwell 1970). Therefore, the best approach for pine engraver control in young stands is thinning during the fall or winter months (Mitchell and Sartwell 1974, p. R-7).

Large populations of engraver beetles can also exist in fresh green logging residue from overstory removal. Thinning the stand before beetle emergence adds food to further increase beetle populations. This in turn causes epidemic outbreaks on residual trees. Since emergence normally occurs throughout the summer, thinning should be postponed until beetle flights have ceased, usually sometime in the fall.[34/]

IN-9 Protecting Uncut Timber from Attack by Western Pine Beetle

Extensive tree killing by the western pine beetle in logged ponderosa pine stands occurs primarily while nearby green residues are under attack (Craighead et al. 1927, Miller and Keen 1960). Disposal of the residue before it is attacked is the best method of keeping western pine beetle populations to endemic levels (Mitchell and Sartwell 1974, p. R-6).

The consensus of the Insects Panel is that a practical minimum requirement is to arrange the residue so it is at least 35 feet from standing trees.

IN-10 Preventing Buildup of Western Pine Beetle Broods

Tree killing by western pine beetle in association with blowdown and wildfire occurs primarily after population buildup in these residues (Miller and Keen 1960; Mitchell and Sartwell 1974, p. R-6). Salvage of windthrown or fire-injured or killed trees is an effective means of reducing beetle populations and subsequent damage (Mitchell and Sartwell 1974, p. R-6).

The consensus of the Insects Panel is that removal of the infested material should take place before developing broods emerge.

IN-11 Controlling Insects with Public Funds

The consensus of the Private Lands Management Decisions Panel is that insect infestations threatening several forest properties are the concern of more than the individual owners. The Insects Panel believes that when such populations are found and declared by the appropriate State Forester to be a zone of epidemic insect infestation, public funds should be made available for insect control.

[34/] Robert E. Dolph, Jr., USDA Forest Service Regional Office, Region 6, Portland, Oregon, personal conversation, 1974.

RE--RECREATION GUIDELINES SUPPORTING INFORMATION

Forest residues guideline statements for protection of esthetic quality were developed from a focus on forest recreation use. This focus brought differing views of what constitutes acceptable esthetic quality into a common field--the way recreationists perceive and enjoy forest surroundings.

Differences in perception, including disagreement among observers as to the nature and content of a given scene, have been attributed to differences in training and experience as well as to other factors such as perceptual capacity (Vernon 1962; Wagar 1974, p. H-2). These differences in perception can reach extremes among the many individuals who make various uses of the forest and who may express strong opinions about "an optimum forest management" for differing combinations of uses. Despite great diversities in background, recreationists are all seeking forest areas pleasing and appropriate to enjoyment of particular activities, but what is sought may change when an individual's role changes, as for example, from "seeker of scenery" to "hunter" (Wagar 1974, p. H-8).

Knowledge about the choices and the reactions of recreation users can lead to description of different forest environments satisfying their quests. But the quantity of these different forest environments to be provided is a matter of land use planning, not residues management. Missions and goals of various ownerships, cost and profitability of alternative uses, demand, and many related elements must be considered in land use planning, but these were beyond the scope of the Recreation Panel.

Recreation Panel members directed their efforts to defining a set of premises about forest environments that satisfy recreationists. The Recreation Panel next chose a system of visual resource classes for classifying forest scenes, or "visual resources," for recreation use. The premises were then translated into guideline statements appropriate to protecting the esthetic quality requisite to recreation enjoyment in each visual resource class.

The basic premises regarding forest recreational environments are covered in RE-1--the basis for each related statement presented in the Public Lands Guidelines (chapter III). Because of the differences in goals between public and private ownerships, statements 1.503 through 1.527 are limited to areas classified under the visual classification system chosen by the Panel. For areas which are not so classified, a more general approach has been taken in statements 1.501 (see RE-1, p. 202) and 1.551 (see RE-2, p. 207). RE-3 (p. 208) and RE-4 (p. 208) cover circumstances where benefits to recreation use must be balanced against trade offs necessary to the overall protection of the forest environment; these trade offs call for special treatments within areas classified for protection of esthetic quality.

Input Block 4 of the User's Work Form (chapter II) for sorting guideline statements shows the system for classifying visual resources described in RE-1 (p. 202). The relationships diagrammatically presented there will help land managers who have no formal system for visual resource classification but who may elect to define equivalent classifications to use the sorting form in chapter II as access to appropriate guideline statements.

Relating Premise Statements to a Visual Resource Classification System

The Recreation Panel agreed on certain premises about the visual resources requisite to forest recreation. They also agreed on a system for classifying the visual resources. Both the premises and the classification system were adapted for residue management by the Recreation Panel from a publication on landscape management developed for use in the National Forests of Oregon and Washington (USDA Forest Service 1974). These premises, as adapted to all forests, are quoted along with other agreed on premises in the following discussion.

Development of General Premises

Expected Images Exist

> The majority of recreation-oriented people who visit...[forests]... have an image of what they expect to see. Such an image or mental picture is generated by available information concerning a particular area and the person's experience with that or similar areas. The image produced represents the knowledgeability, expectedness, romanticism, and emotionalism associated with features within the area. Obviously, several images may exist simultaneously, even within a single individual, and yet a particular geographic region tends to have an identifiable image.[35/]

The following are also quotations (USDA Forest Service 1974):

> Although studies of people's images of forest areas result in varied responses from one geographic region to another, one factor generally remains constant. People expect to see a naturally appearing character within each general Region.
>
> *Aesthetic Concern Varies and Types of Viewers Are Critical*
>
> It is assumed that esthetic concern varies among National Forest users. Those people most concerned about aesthetics are those who are in an area because of, or have a major interest in, the scenic qualities, e.g., recreation area residents and travelers.
>
> *View Duration Is Critical*
>
> The visual impacts of management activities increase as the duration of view increases beyond a quick glance. Examples are those areas seen from vista points, visitor centers, end of road tangents, etc.

35/ Floyd L. Newby. Environmental impact appraisal of proposed developments in Harney Peak area of the Black Hills. Unpublished manuscript on file, Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif. [n.d.].

Number of Viewers Is Critical

The visual impacts of a management activity become more important as the actual or potential number of viewers increases.

All Lands Are Viewed

Because all National Forest lands can be seen from aircraft or high vista points, a minimum [acceptable] visual quality objective should be determined.

Diverse Landscape Character Is Important

All landscapes have a definable character and those with the greatest variety or diversity have the greatest potential for high scenic value.

Retention of Character Is Desirable

Landscapes with distinctive variety in form, line, color, and/or texture should be retained and perpetuated.

The Capacity of Each Landscape to Absorb Alteration Without Losing Its Visual Character Is Critical

Each landscape unit has its individual capacity to accept alteration [modification] without losing its inherent visual character. This may be expressed in the screening ability of the vegetation and landforms, the variety of vegetative cover and rock outcrops and water, and its ability to recover vegetatively after disturbances.

The Visual Impact and Character of Management Activities Is Critical

The visual impact of management activities increases as the amount of landscape alteration increases. The visual impact of management activities generally increases as the visual elements in the management activity deviate from the same elements [expected] in the natural landscape.[36/]

Focus of Viewer Attention Is Critical

The dominance and arrangement of elements will focus viewer's attention and subject certain areas to critical scrutiny. Major peaks, water forms, rock outcrops, meadows, edges, enframed views, axial patterns and convergent patterns are typical areas of focalization. The visual impact of management activities increases as the focus of viewer attention increases in such managed areas.

36/ This premise is supported by the findings of studies which have been further interpreted to suggest that many visitors will overlook or wish to encounter debris from natural, or natural-appearing, causes. Natural debris from some causes may, nevertheless, be damaging to recreation and scenery (Wagar 1974, H-2).

Alteration of Character [Landscape] May Be Desired

Landscapes with little or no variety may be enhanced by alteration.

Viewing Distance Is Critical

Visibility and clarity of detail is often a function of viewing distance. The visual impact of management activities usually increases as viewing distance decreases.

Viewing Angle Is Critical

Visual impact of management activities increases as the viewer's line of sight tends to become perpendicular to the slope upon which the management activity is to take place.

Management Is Necessary

Landscapes are dynamic and even those areas of high aesthetic value may require some management activity to retain the valued character.

Additional Premises

Other variables which affect the system [esthetics] indirectly are motion of activity, lighting, weather conditions, and season of the year....

A System of Visual Resource Classification
Drawn From Certain General Premises

The *first order* classification is based on *viewing distance*. The first order classes,[37/] in descending order of need for protection of esthetic quality, are:

FOREGROUND--variable distance, up to one-half mile from viewer
MIDDLE GROUND--variable distance, between one-half mile and 5 miles
BACKGROUND--beyond 5 miles

Second order classification is based on amount of *landscape alteration*. Further subdivision of each first order class depends on the extent to which visual elements in management activities deviate from the same elements expected in the natural landscape. The second order classes[38/] (visual quality objectives) in descending order of need for protection of esthetic quality, are:

37/ In the developed system (USDA Forest Service 1974).

38/ In the developed system (USDA Forest Service 1974).

PRESERVATION--allows natural changes only

RETENTION--permits management activities that are not visually evident

PARTIAL RETENTION--permits management activities visually subordinate to the characteristic natural landscape

MODIFICATION--permits management activities to dominate original characteristic landscape

MAXIMUM MODIFICATION--permits vegetative and landform alterations to dominate the characteristic landscape

Third order classification is based on *duration of view*. The following terms were developed by the Panel for subdivision of second order classes. These third order classes, in descending order of need for protection of esthetic quality, are:

OCCUPANCY AND WANDER THROUGH

LOW SPEED TRAVEL PAST--30 MPH OR LESS

HIGH SPEED TRAVEL PAST

Fourth order classification is based on *density of screening* (capacity of landscape to absorb modification). The following terms were developed by the Panel for subdivision of third order classes. These classes, in descending order of need for protection of esthetic quality, are:

LITTLE OR NO DENSITY OF SCREENING

MODERATE DENSITY OF SCREENING

HEAVY DENSITY OF SCREENING

Interpretations and Additional Premises Applied to the Adapted Classification System

Levels of protection of esthetic quality can be developed for the classes and subclasses defined above. Each class and subclass in the adapted visual resource classification system has a descending order of need for protection of esthetic quality, making it possible to scale what is expected.

In addition to interpretation of the general premises on a scale running from most to least stringent, the following list should further scale the end result of management actions called for in the guideline statements. These adjectives are taken from a "Landscape Adjective Checklist" (LACL) (Craik 1972, cited in Wagar 1974, p. H-3). The lists, drawn from a limited though statistically significant study, are repeated here for possible use by land managers.

LACL for Esthetically Unappealing Scenes

arid	destroyed	scraggly
bare	dirty	ugly
barren	drab	unfriendly
bleak	dry	uninspiring
brown	dull	uninviting
burned	eroded	weedy
bushy	golden	windswept
colorless	hot	withered
depressing	lifeless	worn
deserted	monotonous	yellow
desolate	plain	

LACL for Esthetically Appealing Scenes

alive	fresh	pure	wild
clean	green	secluded	wooded
clear	living	timbered	
cool	moist	unspoiled	
forested	natural	vegetated	

Specific details were discussed by the Recreation Panel for each class of viewing distance (first order classes):

FOREGROUND--up to one-half-mile:

- Specifications should aim at natural appearance (Wagar 1974, p. H-2), with any management activity being least evident or subordinate (USDA Forest Service 1974).

- For sites likely to be entered, passability (ease of traversing or degree of obstruction) must be considered[39/] (Wagar 1974, p. H-7).

- Residue cleanup will avoid the appearance of waste, an objectionable condition to many viewers[39/] (Wagar 1974, p. H-7).

- Size and arrangement of residue pieces are more important close to the viewer than in the distance, especially for partial retention and modification conditions.

- Higher stumps and more and larger residue pieces may be left with screening.

- Areas normally viewed from cars passing at high speed may have more and larger residue pieces and higher stumps than areas normally viewed at low speeds.

[39/] Randel F. Washburne, Roger F. Clark, Frederick Campbell, and others. Panel report on aesthetic objections to forest residues. Unpublished manuscript on file, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon [n.d.].

- Under maximum modification conditions, passability, appearance of waste, and disposal of manufactured waste materials (oil drums, cable, and trash) are the only important esthetic considerations.

- More stringent esthetic conditions require low-cut stumps and may call for camouflaging of cut faces with dirt or moss.

- Bare soil is displeasing[39/] especially where piled or dug up, or where it contrasts with humus or duff in undisturbed areas.

- In more stringent conditions, the density and character of vegetation in areas where timber is harvested should approximate that in surrounding areas.

- Burned areas resulting from piling and burning of residues are undesirable in increasingly stringent esthetic situations.

MIDDLE GROUND--between 1/2 mile and 5 miles:

- Skidding patterns are obvious and undesirable in the most stringent specifications.[39/]

- Controlling texture (pattern) produced by residue pieces[39/] (Wagar 1974, p. H-6) by limiting size and density is more important with increased esthetic stringency.

- Patterns of disturbed soil and burning are undesirable as discussed under "Foreground."

BACKGROUND--beyond 5 miles:

- Most features of forest residues and residue treatments are not evident at background distances. Areas classified as background are, however, subject to some public use. Although background should thus meet minimum standards for passability, appearance of residue, and disposal of manufactured waste materials (oil drums, cable, etc.), the consensus of the Recreation Panel was to not develop statements for areas so classified.

RE-2 Protection of Esthetic Quality on Lands Used for Recreation But Not Under a Formal Visual Resource Classification System

Some public and private lands are little used for recreation because the nonrecreation goals of the owners, or the goals established in law for some public lands, limit opportunities for such use. Access may be restricted or may be undeveloped. Formal classification of the visual resource on such lands either may be unnecessary, or equivalent classifications for those shown in Input Block 4 of the User's Work Form or a simplified system may be used.

If visual resource classification is unnecessary but some recreation use is encouraged, goals of keeping man-caused residues subordinate to the characteristic landscape are desirable in areas where use is encouraged (Wagar 1974, p. H-5 and H-7).

In areas of lesser use, decomposition should be hastened and the appearance of waste and disorder minimized (Wagar 1974, p. H-7, H-11, and H-12).

RE-3 Recreational Benefits from Exceptions to Recreation Guidelines

Certain guidelines for esthetics and forest protection (List 1.000 statements) may be modified for silvicultural and terrestrial habitat purposes (List 3.000 statements). Such modifications also provide benefits to recreation. These may include improving the forest appearance by treatment to enhance the establishment of new trees and improving chances for sighting of wildlife by removal of residue.

Wherever exceptions are made to the List 1.000 statements, manipulation must be done in a manner that avoids public misunderstanding, deviates as little as possible from List 1.000 statements, and gives the impression of having been done carefully as part of a coherent pattern of land stewardship (Wagar 1974, p. H-5).

RE-4 Compensatory Benefits to Overall Forest Protection from Exceptions to Recreation Guidelines

Although natural debris may be acceptable to visitors, it may nevertheless be damaging to recreation and scenery (Wagar 1974, p. H-2). The massive amounts of debris resulting from events such as wildfire, epidemics, and violent storms are considered in this category.

Removal of much of this debris may benefit many aspects of environmental quality, including avoidance of losses of vegetative cover from fire, insect attack, and disease. Where overall forest protection will benefit from debris removal, certain guidelines drawn from List 2.000 apply. These guidelines prescribe treatments necessary to provide adequate fuel management and to prevent spread of insects and disease. Wherever these supplementary conditions are attached to List 1.000 statements, attention should be given to achieving what people associate as natural in the area of treatment (Wagar 1974, p. H-5). Natural appearance is aided by softening the edges of any openings through gradual transition from cleared areas to forest; i.e., by "feathering" (Wagar 1974, p. H-6).

SI--SILVICULTURE GUIDELINES SUPPORTING INFORMATION

SI-1 The Need for Eliminating Residues Which Are Obstacles to Management

Timber harvesting and silvicultural operations in the Pacific Northwest can produce unacceptable accumulations of residues. These residues may obstruct regeneration and impede planting, future harvesting, silvicultural activities, recreation, and efficient forest management (Dell and Ward 1971; Edgren and Stein 1974, p. M-1 and M-4 to M-6; Ruth 1974, p. K-9).

The consensus of the Silviculture Panel is that forest residues created by silvicultural activities should be treated to eliminate obstacles for future silvicultural activities or timber harvesting.[40/]

SI-2 The Need for Space for Prompt Reestablishment of Timber Species

To meet an objective of utilizing the full growing capacity of forest lands, prompt reestablishment of preferred timber species is needed after any harvesting that more than thins the stand. Some species in some situations may become established on rotten residues, e.g., in coastal hemlock-spruce forests (Ruth 1974, p. K-8). Also, conditions most favoring germination of seed may be at variance with conditions most favoring seedling survival, e.g., white fir in mixed conifer stands on the west slope of the Sierra Nevada (Stark 1964, cited in Seidel 1974, p. L-7). Nevertheless, some generalizations regarding space for prompt reestablishment can be made:

For areas to be planted in the Olympic and Coast Range Provinces, the consensus of the Silviculture Panel, was that any time the number of crop trees was reduced below 70 trees per acre, 11-inch d.b.h. or larger, there should be at least 350 planting spots and/or established seedlings or saplings uniformly distributed on each acre. In these geographic areas, an acceptable planting spot conforms to the concept presented in the paragraph on planting spot acceptability and is free of established salmonberry (Miller et al. 1974, p. J-10).

For areas to be planted in all other specified forest residue type areas, the consensus of the Silviculture Panel was that any time the number of crop trees was reduced below 40 trees per acre, 11-inch d.b.h. or larger, there should be at least 190 planting spots and/or established seedlings and saplings uniformly distributed on each acre.

For all specified areas where planting is to be done, the following additional statement of planting spot acceptability applies: Every acceptable planting spot must be accessible to planters and protected from soil ravel; for example, downslope from stumps or logs which are preferably bark free (Edgren and Stein 1974, p. M-6 and M-11). For sites where sunshine may be expected to cause mortality, planting spots will have partial shade (Edgren and Stein 1974, p. M-12 to M-14; Seidel 1974, p. L-7; Miller et al. 1974, p. J-10) from the south and west sides in the form of rocks, stumps, and logs (Ruth 1974, p. K-7), which are preferably bark free (Edgren and Stein 1974, p. M-6). Rotten wood is acceptable as a planting medium in the coastal hemlock-spruce type (Berntsen 1960, cited in Ruth 1974, p. K-9) but is to be avoided for planting spots in the remaining mixed-conifer types (Ruth 1974, p. K-9) and is not desirable on sites with extreme conditions (for example, steep south slopes with shallow soil (Miller et al. 1974, p. J-4)). Skid roads and other compacted areas should be avoided, as should those with partially buried residues, or where chips may become mixed with the soil surrounding the planted tree (Edgren and Stein 1974,

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[40/] Edgren and Stein (1974, p. M-6) make the point that, although the obstruction effect is recognized by most people, very little data have been published; but they suggest the resistance to control rating used in fire management may correlate with obstruction to planting (see FI-2, p. 183, on rating resistance to control).

p. M-7 and M-10). Generally, residual vegetation may provide beneficial shade and protection from frost (Youngberg 1966) and is thought to be of little consequence in successfully regenerating Douglas-fir, with certain notable exceptions. Salmonberry has been previously mentioned on page 209. Swordfern and oxalis communities become increasingly vigorous after clearcutting on moist sites of the western Cascade Range. On such sites, planted trees either should be shade tolerant or should be expected to maintain dominance over the residual vegetation (Miller et al. 1974, p. J-5 and J-10). If not, vegetation should be avoided in selecting planting spots.

In certain areas where seeding is to be practiced or where natural regeneration is to be the means of achieving stocking, a uniform distribution of spots similar to those described above will be needed as well as an exposed mineral soil seed bed. There is general agreement on the desirability of a mineral soil seed bed for favoring survival and growth of Douglas-fir (Miller et al. 1974, p. J-25), as well as all species in the pine and mixed-conifer types east of the Cascade Range (Seidel 1974, p. L-8). Mineral soil seed bed is also necessary in the mixed-conifer stands west of the Cascade Range, with the exception of hemlock-spruce in partial cut stands (Ruth 1974, p. K-8 and K-9).[41/]

SI-3 The Need for Protection of Seedlings by Leaving a Portion of Forest Residues Untreated

Miller et al. (1974, p. J-10) cite Silen,[42/] Hallin (1968), and Fowler (1974) in stating that a major benefit from slash is that it provides numerous patches of shade throughout cutover areas, thus moderating high and low surface temperatures. They also credit slash with reducing mortality of Douglas-fir reproduction from freezing, frost heaving, heat lesion, and drought. General agreement is reported on similar benefits to both tolerant and intolerant pine species east of the Cascade Range, including a study in lodgepole pine in which light to moderate slash on scarified areas yielded improved first-year survival over scarified plots with no slash protection (Cochran 1973, cited in Seidel 1974, p. L-7). Regarding lodgepole pine, Seidel (1974, p. L-8) further states that where it occurs as a seral species in mixed conifer forests, it regenerates satisfactorily with no overhead shade. However, in the pumice plateau area of central Oregon where this species forms climax stands, a light amount of logging residue seems to have a favorable effect. For the mixed conifers of western Oregon, Ruth (1974, p. K-7) cites Hallin (1968), Minore (1971), and Isaac (1938) in documenting the need for shade. He also points out that the net effect of residues is variable, but their presence does reduce frost damage on numerous microsites.

41/ Additional references in the cited literature and in Edgren and Stein (1974) form the basis for statements interpreted and cited in this discussion on seed bed preparation: Alexander (1966), Berntsen (1955), Boyd (1969), Boyd and Deitschman (1969), Fowells (1965), Fowells and Stark (1964), Hall (1971), Hermann and Chilcote (1965), Isaac (1943), Lotan (1964), Roy (1953), Trappe (1959).

42/ Roy Ragnar Silen. Lethal surface temperatures and their interpretation for Douglas-fir. Ph.D. thesis, Oregon State College, Corvallis, 1960.

The importance of shade is further emphasized by Berntsen (1955), Hermann (1963), Ronco (1970), Ryker and Potter (1970), Stoeckeler (1945), and Strothmann (1972). In addition to moderating temperature, dead residues such as slash slow moisture loss. Edgren and Stein (1974, p. M-14) cite Cochran (1973) regarding protection of seedlings from low temperatures by slash which reflects the outgoing radiation back to the ground. Fowler (1974, p. N-11 and N-14) presents a case for using the aerodynamic roughness of slash on a slope for stirring the dense, cold air which tends to move downslope and settle in depressions, causing frost damage. Residues also reduce damage to timber species by limiting access of browsing animals (Ruth 1974, p. K-8; Dimock 1974, p. O-5; Edgren and Stein 1974, p. M-6) and may help hide some seed of commercial species from birds (Dimock 1974).

In addition to serious detrimental effects of residues discussed in SI-1 (p. 208), SI-2 (p. 209), and SI-4 (p. 212), and documented for several guideline statements (such as for esthetics, fire, insects, and disease), other detrimental effects must be evaluated. The effect on microenvironments can be either beneficial or detrimental, depending on the depth of the residues. For example, Fowler (1974, p. N-14) points out that with increasing depth, air exchange within the zone near the soil surface can become restricted. He states that plants in such environments can be effectively "buried" with excessive residue accumulation if the minimum air exchange is not met for removal of toxic gaseous products. Even deformation of seedlings and small saplings by bending and twisting, though not regarded as a normally serious problem, should be recognized as an effect of slash (Seidel 1974, p. L-9).

Besides shade, seedlings also need sunlight. Douglas-fir tolerates light-to-moderate shading of seedlings by residues or by trees left on the site (Miller et al. 1974, p. J-4). Edgren and Stein (1974, p. M-12) cite Berntsen (1955) relative to a preference for light slash in a spruce-hemlock clearcut. Day (1964) found that one-third of the spruce and fir seedlings in a study in Alberta, Canada, occurred where there was heavy shade 50 to 100 percent of the day.[43/] Damping-off fungi are reported to increase seedling mortality under moderate to heavy shading (Miller et al. 1974, p. J-4).

From the above discussion, it is apparent that there is limited knowledge of the beneficial effects of residues on timber regeneration; but many interactions are not accounted for. Fowler (1974, p. N-2), for example, points to the limited availability of literature directly related to effects of residue on microclimate. This accounts for the absence of more precise statements than "light," "moderate," and "heavy" slash when speaking of silvicultural benefits and detriments. In the face of this deficiency, the consensus of the Silviculture

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[43/] Other references have been cited by Edgren and Stein (1974, p. M-12 to M-14) on light intensity and are specific to species. These include reports of studies which should be useful in arriving at more quantitative expressions of desired shade levels but which may not adequately include such additional variables as reflectance, heat advection, humidity, and soil moisture on the welfare of the trees studied: Adams et al. (1966), Franklin (1963), Garman (1955), Gordon (1970a, 1970b), Hatch and Lotan (1969), Isaac (1943, 1956, 1963), Krauch (1956), Maguire (1955), McCulloch (1942), Minore (1971, 1972a), Pearson (1950), Ronco (1970), Roy (1953), Ryker and Potter (1970), Shearer (1967), Strothmann (1972), Wahlenberg (1930).

Panel was to leave a per-acre maximum of no more than five 80-cubic-foot pieces (representing wood pieces 24-inch diameter, small end, by 25 feet long, and 40-inch diameter, small end, by 10 feet long, etc.). The Silviculture Panel further agreed that leaving smaller material, as permitted by other guidelines, would satisfy requirements for clearcut areas for which leaving certain amounts of logging slash was recommended.

SI-4 The Need for Control of Competition from Living Residues

Crop trees of intolerant species such as Douglas-fir need to maintain dominance over their competitors (Miller et al. 1974, p. J-5). The effect of competitors upon available light and soil moisture is of prime importance (Edgren and Stein 1974, p. M-2, M-3, M-12 to M-14, and M-16) in deciding when and if to control competition from living forest residues.

The Silviculture Panel has established a requirement for control of brush species during the first 5 years before dominance of crop trees is lost or growth of crop trees is limited by competition for sunlight or soil moisture. The Silviculture Panel has assumed that detailed judgments will be made by land managers for each case. For soil moisture determination, it will be necessary to do more than judge height or quantity of competing vegetation. For this purpose, available soil moisture during critical seasons should be compared with the known effects of different stress levels. Soil water potentials of -2 to -4 bars may reduce seedling growth. A reduction of 0.5 bar may affect stem elongation and dry weight production. Water will become less available as soil moisture decreases. However, there is no definite point at which water becomes unavailable to plants (Kramer 1969 as cited in Edgren and Stein 1974, p. M-3).

The Silviculture Panel agreed that the need for treating live residues was less critical after the first 5 years. After that time, living residues less than two-thirds the height of crop trees could be tolerated.

SI-5 Damage from Birds and Animals

Numbers and kinds of vertebrates using a forest site are significantly affected by the character, density, and distribution of residues (Dimock 1974, p. O-3). As developed in SI-3 (p. 210), residues can protect tree seedlings from bird and animal predation. Unfortunately, they can also provide habitat for birds and animals which feed on tree seeds and seedlings. For example, logging slash can help to hide some tree seed (see SI-3) but, at the same time, it provides nesting habitat for small seed-eating birds (Dimock 1974, p. O-5). Slash improves the habitat for species such as deer mice, which can devastate Douglas-fir natural regeneration, and which normally do not require dense cover (Dimock 1974, p. O-5; Miller et al. 1974, p. J-4). Dimock (1974, p. O-13) cites Mitchell's (1950) observation that it was necessary to plant trees 5 to 20 feet from brush piles to lessen damage by brush rabbits on western sites and suggests that damage by snowshoe hare may be expected in habitats with prominent slash piles.

Although admitting the weaknesses of experimental data, Dimock (1974, p. O-17) risks some generalizations which include the statement:

> Treatment methods that alter residues the least--although still meeting objectives of reducing fire hazard, lessening waste, and alleviating brush competition--seem to have most practical possibilities for minimizing animal problems.

The Silviculture Panel, while acknowledging the potential benefits of leaving certain residues (see SI-3, p. 210), recognized that the potential of an animal problem associated with residues could best be determined on the basis of local experience and conditions. For this reason, the Silviculture Panel recommended treatment of residues that may provide habitat for development of animal populations that would prevent establishment and growth of adequate numbers of crop trees. Their recommendation implies a need for local observation, preferably by experts in both silviculture and animal habitat.

SI-6 Use of Prescribed Fire Recommended

Prescribed fire may be used to reduce both logging slash and potentially competitive vegetation in clearcut areas. It may also be used in forest stands to reduce the natural litter from stand atrophy and understory vegetation in either uncut stands or in partially cut stands along with the slash from partial cutting. When used in clearcut areas or for type conversion, the fire prescribed is usually more intense than fire used in uncut or partially cut stands. The former is known as broadcast burning and the latter as underburning.

Fire prescriptions, their relationship to a natural role of fire in certain northwestern ecosystems, and the Fire Management Panel recommendation that fire be used in certain Forest Residue Type Areas, are covered in FI-11 (p. 195). Silvicultural use of prescribed fire requires preparation. For minimum difficulty in control of fire and threat of damage to adjacent timber, slash from logging and timber culture operations should be arranged so as to avoid piles or concentrations against uncut timber. Judicious rearrangement of fuel can measurably improve the reintroduction of fire to forest areas where its long-time exclusion has resulted in excessive fuel accumulations that now make fire restoration a difficult task.

Seidel (1974, p. L-10) cites Weaver (1967) who stresses the importance of fire in maintaining ponderosa pine and who also discusses the effects of excluding fire. Gratkowski (1974, p. I-9), in pointing to both the advantages and disadvantages of using prescribed fire, introduces the use of chemical desiccants along with controlled burning for certain situations. He also points out that chemicals are not as effective against some species as is fire for initial treatment and as a subsequent control for reinvasion or resprouting.

In recommending fire for control of invading species and for seed bed preparation, the Silviculture Panel consensus was that 20 percent is the maximum reduction in timber growth rate which can be tolerated. It was the view of this Panel that the use of prescribed fire should be among the alternatives considered whenever the growth rate is threatened to this extent by invading vegetation.

SO--SOILS GUIDELINES SUPPORTING INFORMATION

SO-1 Soils of Medium and Fine Texture

Soils of this group have a tendency to be compacted readily by equipment (Rothacher and Lopushinsky 1974, p. D-7 and p. D-8; Ruth 1974, p. K-14; Gratkowski 1974, p. I-12). Moisture content in these soils becomes especially critical when soil moisture exceeds about 10 percent. Soil compaction is most frequently a factor in evaluating which equipment to use for piling and burning, crushing,

and YUM (yarding unutilized material) operations. The consensus of the Private Lands Management Decisions Panel is that equipment exerting less than 3½ pounds per square inch will have little effect on compaction.

SO-2 Soils of Coarse Texture

Soils of this group contain 50 percent gravel or larger size fragments. Texture governs the treatments which would increase the erosion rate of coarse-textured soils or increase the rate of gravel or stone raveling on the soil surface (Rothacher and Lopushinsky 1974, p. D-7). Soil textures include sandy loam, loamy sand, and sand. These soils also are most susceptible to nonwettability resulting from fire (Miller et al. 1974, p. J-16).

SO-3 Soil Organic Matter of Less Than 2-3 Percent

Soil organic matter content of 2-3 percent is recognized as a critical minimum by consensus of Soils Panel. Organic matter plays important roles in both physical and chemical properties of the soil that control water movement and available plant water storage, soil stability, and general life of the soil (Rothacher and Lopushinsky 1974, p. D-7 and D-8). As broadcast burning of residues usually results in destruction of organic matter, soils in which the reserve is already very low should not be subjected to this treatment. Low intensity spring burns which do not destroy the duff generally do not materially affect soil organic matter functions. The Private Lands Management Decisions Panel agreed that leaving materials less than 3 inches in diameter would help offset soil damage resulting from machine piling on soils of low organic content. The Public Lands Management Decisions Panel agreed to limit the mineral soil exposed during broadcast burning on low organic matter soils to 20 percent of the area being treated. (See SI-3, p. 210.)

SO-4 Soil Depth of Less Than 24 Inches

Reduction in soil depth is considered important, particularly in combination with residue disposal by burning, because both reduce nutrient and water storage. With deep soils, the reserve is large and reductions are of little consequence; but when the reserve is low as in shallow soils, reduction of depth may be crucial (Ruth 1974, p. K-7; Seidel 1974, p. L-6; Gratkowski 1974, p. I-10). The Soils Panel has arbitarily designated 24 inches as a critical minimum soil depth. The Private Lands Management Decisions Panel agreed that leaving materials less than 3 inches in diameter would help offset soil damage resulting from machine piling on shallow soils. (See SI-3, p. 210.)

SO-5 Low Soil Fertility

Low soil fertility contributes to slow growth of timber and associated understory plants. Soils with low fertility require conservation or improvement of existing plant nutrients. Practices such as burning or complete YUM yarding which tend to deplete nutrients are detrimental to site productivity. Crushing and incorporation of residue into the soil are also detrimental since this results in an immediate, though temporary, reduction of nitrogen, an essential plant nutrient. These effects on plant nutrients have been documented (Ruth 1974, p. K-7, p. K-14, and p. K-15; Seidel 1974, p. L-6; Gratkowski 1974, p. I-20; Miller et al. 1974, p. J-11 and J-12). A 3-inch maximum diameter for materials to be left in place is intended to leave most of the foliage since this residue component yields most of the essential elements.

Fertilization to offset effects of residue treatments on nutrients should be specified on the basis of factors such as: intensity of burn, though effects on nutrients have been controversial (Miller et al. 1974, p. J-13; Moore and Norris 1974, p. C-13); the presence of nitrogen-fixing species such as alder (Moore and Norris 1974, p. C-4); the rate of return to normalcy after treatment (Moore and Norris 1974, p. C-10) in relation to management goals; and the extent to which residues are mixed with the soil.

SO-6 Available Soil Moisture Holding Capacity of Less Than 2 Inches Per Foot of Soil

Soils with less than 2 inches available water per foot of depth are considered by the Soils Panel to be droughty soils. Infiltration rates should be protected and a surface organic mulch preserved to reduce soil moisture loss. This situation is commonly associated with shallow, coarse-textured soils. Practices negatively affecting this situation are broadcast burning and piling and burning (Gratkowski 1974, p. I-20). The consensus of the Public Lands Management Decisions Panel is that a 25-percent shade cover in certain cases should offset the loss of moisture holding capacity associated with machine piling of residues. Similarly, the Private Lands Management Decisions Panel agreed that sufficient shade for seedling establishment should offset the removal of residues. (See SI-3, p. 210.)

SO-7 Litter Less Than 1 Inch Deep

Litter on the soil surface serves several important roles including shading, reducing raindrop impact, and slowing overland flow. Sites on which this restriction of litter removal applies are generally hot, southerly exposures frequently with low amounts of plant-available moisture. The consensus of the Soils Panel is that litter of at least 1-inch depth should be present over at least 70 percent of the land area. This should provide minimum satisfactory soil protection where raindrop impact, overland waterflow, and wind erosion are likely to occur (Bollen 1974, p. B-27; Ruth 1974, p. K-7; Gratkowski 1974, p. I-10).

Pure ponderosa pine and juniper stands are excluded because site potential and climate preclude development of 1 inch of litter. Bunchgrasses commonly form ground cover under these open (savanna) stands. Bunchgrass litter tends to blow away, and tree cover is not sufficient to produce 1 inch of litter. Fire scars on trees testify to a history of repeated natural underburnings.

Depth and distribution of litter are most strongly affected by broadcast burning, piling and burning, and ground contact YUM yarding.

SO-8 Slopes of 30 to 60 Percent

Slopes greater than 30 percent without roads pose severe limitations to track and wheeled equipment. The 60-percent slope is approximately the natural angle of repose. Experience has shown that erosion increases severely on slopes greater than 60 percent after burning (Rothacher and Lopushinsky 1974, p. D-10). The consensus of the Private Lands Management Decisions Panel is that slope-related limitations on residue treatment should begin at 35 percent for all provinces except the Siskiyou where limitations should begin at 30 percent.

SO-9 Slopes Greater Than 60 Percent

Steep slopes near or above the natural angle of repose (approximately 60 percent) are a hazard to several forms of fuels management. These slopes are susceptible to sliding and are very likely to be subject to overland flow and soil erosion (Rothacher and Lopushinsky 1974, p. D-10; Ruth 1974, p. K-7).

Broadcast burning on such slopes may reduce the amount of root binding and hence increase soil sliding. Such steep slopes generally burn very hot, hence lose any protective cover of vegetative material. This accentuates the problem of overland flow by increasing erosion rates. Use of equipment on such steep slopes, as for crushing or piling, leads to very serious soil displacement and erosion. Ground contact YUM yarding on these slopes also tends to reduce the protective ground cover.

SO-10 Treatment Less Than 100 Feet From Live Stream

This restriction is meant to protect the stream from sediment from adjacent sources. It is generally applied where overland flow could be expected after fuels treatment (Rothacher and Lopushinsky 1974, p. D-10, D-12, and D-13). Distances mentioned in the guidelines are the arbitrary judgment of the Soils Panel.

SO-11 Extension of Reliance on Fire Prescriptions That Will Avoid Destruction of the Duff Layer

The consensus of the Private Lands Management Decisions Panel is that, in certain areas where the Soils Panel holds the view there are not now adequate fire prescription criteria for soil protection: (a) experienced prescribed burners have demonstrated that reasonable precautions to protect the duff layer are possible; (b) the art of prescribed use of fire is making rapid advances; (c) current research and development toward reliable duff-protecting prescription criteria are progressing at a pace that should make these criteria available soon. (See FI-11, p. 195.)

SO-12 Southerly Exposures

Certain residue treatments such as broadcast burning, piling and burning, and YUM increase south slope temperatures and dryness, thereby increasing survival problems of regeneration and vegetation cover (Aho 1974, p. Q-7). In the consensus of the Public Lands Management Decisions Panel, a 25-percent shade cover in certain cases should offset problems associated with machine piling of residues. Similarly, the Private Lands Management Decisions Panel agreed that sufficient shade for seedling establishment should be encouraged to offset the removal of residues. (See SI-3, p. 210.)

SO-13 Frost Heaving

Limitations are suggested for soils which tend to frost heave planted and natural seedlings. These limitations are most often applied to practices which leave no insulative layer of organic litter following treatment (Ruth 1974, p. K-7). Mulching (Fowler 1974, p. N-13) and shading (Miller et al. 1974, p. J-10) with residues may help to reduce frost heaving and seedling dislodgment. The consensus of the Public Lands Management Decisions Panel is that a 25-percent soil shade cover in certain cases should offset frost heaving problems associated

with machine piling of residues. Similarly, the Private Lands Management Decisions Panel agreed that sufficient shade for seedling establishment should be encouraged to offset the removal of residues. (See SI-3, p. 210.)

SO-14 Subalpine Forests (Timber Species Association 5)

Management of harvesting residue and subsequent regeneration on subalpine forests frequently presents different problems because of the nature of the organic matter accumulated during the development of the forest. This forest area is characterized by low average temperature and summer moisture deficiency so that decomposition is slow, resulting in large surface accumulations of organic matter. These can build up to depths of 14-18 inches with a total weight of 6-12 tons of dry matter per acre.

After removal of overstory, this material dries out rapidly and not only constitutes a large amount of combustible material but is frequently a barrier to forest regeneration.

There is generally little incorporation of this organic matter into the upper soil layers, and mineralized nitrogen is frequently low. The material itself displays distinct hydrophobic properties when dry, and initial rains tend to run off the surface and may contribute to rapid streamflow peaks.

Residues from forest harvesting need special consideration because residue treatment here may contribute additional problems or may be used to ameliorate existing conditions. For instance, complete destruction by fire would remove much of the stored nitrogen, with very slow rates of recovery. Advance regeneration, frequently found under the harvested stand, is also destroyed, and large amounts of ash material and soluble chemicals may be released to nearby streams.

A system that brings about a mixing of logging residues with the forest floor and with the underlying mineral soil is to be preferred. From the point of view of overall forest management, the more complete the mixing, the better for future development of the ecosystem.

SO-15 Dunal Subprovince

These soils are dominantly coarse and highly erodible by wind and water. Small gouged areas can readily grow to depressional "blowouts." Even small areas of surface exposure can erode. Any operation in this soil province must be governed by strict attention to preventing any disturbance that may lead to "blow" conditions.

Also, these soils are highly displaceable. Any use of machinery or log gouging can remove the weakly developed soil, leaving behind an infertile soil material.

The consensus of the Soils Panel is that there should be no disturbance, or displacement, of soil in this area.

SO-16 Combinations of Above

In certain forest type areas, combinations of many of the above critical soils factors are so frequent and of such importance that any disturbance is undesirable. Lopping and scattering of forest residues is specified as the preferred treatment for such areas since it is least disturbing.

TE--TERRESTRIAL HABITAT GUIDELINES SUPPORTING INFORMATION

TE-1 Broadcast Seeding

When forest vegetation is killed or destroyed and soil is exposed, watershed protective value and forage for wildlife and domestic livestock are lost. In most cases nitrogen-fixing vegetation is reduced, and nutrient cycling is interrupted. Often poisonous or noxious plants invade the area to compete with desired species.

Soil exposed by disturbance or fire offers the land manager an opportunity to seed with plants which are suitable to the site, climate, and use of the land. Seeding promptly after soil disturbance or burning is better land management than waiting 2 or 3 years. Dyrness (1970) pointed out that best success with broadcast seeding occurs while the soil is still loose and friable. The consensus of the Terrestrial Habitat Panel is that seeding should be done within 10 days of disturbance or burning. As time passes, the soil tends to settle and the surface crusts from raindrop impact. This results in erosion and provides a poor seed bed for establishment of ground cover species.

TE-2 Topsoil Replacement

Replacement of topsoil on debris burial pits, or mounds, enhances establishment of ground cover vegetation. The Terrestrial Habitat Panel specifically did not mention animals because many burial sites are located along main roads. In situations where traffic speed is high, use of palatable plants to provide forage for animals is discouraged because grazing animals, particularly big game, pose a serious traffic safety hazard. In these cases, plants of low palatability should be selected to discourage animal use.

TE-3 Use of Prescribed Fire

Broadcast burning of logging slash in Douglas-fir forest types enhances establishment and growth of forage communities desired by big game animals. The quality and quantity of preferred forage can be increased as can the period of optimum habitability (Garrison and Smith 1974, p. P-3 to P-5; Dimock 1974, p. O-7 to O-9). The 50-percent minimum level in Statement 3.804 is the consensus of the Terrestrial Habitat Panel.

TE-4 Soil Disturbance

Avoiding soil in piles of debris permits complete combustion of the residue pile (see AI-4, p. 174) and prevents undue displacement of the soil A horizon. Desired vegetation establishes easier and grows better in relatively undisturbed soil or A horizon than in severely disturbed soil in which the poorly weathered C horizon is exposed. The consensus of the Terrestrial Habitat Panel is that severe soil disturbance and reduction in plant growth should be avoided.

TE-5 Retention of Some Slash Cover in Certain Clearcuts

Retention of undisturbed slash in clearcut areas aids cover and concealment of big game, as well as nongame animals. Literature cited by Garrison and Smith (1974, p. P-2) and Dimock (1974, p. O-5) suggests that some slash should be left untreated but other areas should be treated to improve animal movement and access. The Public Lands Management Decisions Panel agreed that 10 percent of certain clearcut areas be left untreated as a reasonable compromise between fire management, accessibility for intensive stand management, and animal habitat needs. Smaller diameter patches of untreated slash were recommended for small clearcuts where cover around the edge of the clearcut would be adequate for big game animals. Larger slash piles were recommended in larger clearcuts as cover for big game animals as well as small game.

TE-6 Movement of Animals and Wildlife Cover

Reduction of slash to a depth of 8 inches or less on at least 75 percent of an area primarily facilitates livestock movement. The Terrestrial Habitat Panel agreed that 25 percent of an area should be left in untreated slash to provide cover and habitat for wildlife. Slopes greater than 30 percent are exempted because cattle graze with increasing difficulty on steeper slopes.

TE-7 Critical Big Game Habitat

The Terrestrial Habitat Panel believed maintenance of critical-weather big game range to be essential.

In these areas, any significant reduction in bitterbrush will be detrimental to big game. Therefore, primary land management objectives should be to enhance game winter range rather than optimize timber, livestock, or recreational opportunities. Of game winter ranges in the greater Pacific Northwest area, those with bitterbrush are most sensitive to forest residue treatment because bitterbrush seldom sprouts after burning nor can it reproduce from rootstalks following destruction of the aboveground shrub. The Public Land Management Decisions Panel concurred that there should be a program to prevent destruction of bitterbrush in these limited but crucial areas. To survive, bitterbrush plants must be able to sprout and produce new growth the next year.

TE-8 Retention of Bitterbrush

The consensus of the Terrestrial Habitat Panel is that at least 50 percent of the original number of bitterbrush plants should be retained alive after timber harvest and slash disposal in the lodgepole-bitterbrush community of south central Oregon. This community is an important big game spring, fall, and summer range. A key point in this statement is that plants must "survive" logging. This means that bitterbrush plants may sustain damage from logging or slash disposal, such as crushing or breaking, but only to the extent that the plants are able to sprout and produce new growth the next year.

TE-9 Movement of Animals

Any continuous concentration of residues, especially across frequently used livestock and game trails, will greatly restrict movement. This in turn restricts use of forage and movement from forage to water. Such obstruction is very disruptive and detrimental to the habits and needs of both domestic and wild grazing animals (Garrison and Smith 1974, p. P-3; Dimock 1974, p. O-5). By consensus of the Terrestrial Habitat Panel, any material larger than 3 inches in diameter or higher than 6 inches above the soil is considered disruptive.

TE-10 Huckleberry Areas

One of the major factors in reducing huckleberry production is the encroachment on huckleberry fields by pioneer tree species, such as lodgepole pine and mountain ash (Minore 1972b). The Terrestrial Habitat Panel members and several professionals on the Gifford Pinchot National Forest intimately familiar with the Twin Buttes huckleberry field believe that pine species should be removed first. The Terrestrial Habitat Panel concluded that three to five fir or hemlock trees per acre tend to modify the microclimate favorably for huckleberries. These three to five trees per acre tend to produce no more than 10 to 20 percent of ground cover and therefore, apparently, do not significantly reduce berry production.

TE-11 Movement of People in Berry Areas

The consensus of Terrestrial Habitat Panel members is that removal of logs would reduce barriers to people moving through clearcuts to pick huckleberries and would improve berry production. Although little is known about managing northwestern huckleberries (Minore 1972b), broadcast burning, according to observations of personnel of the Gifford Pinchot and Mount Hood National Forests, tends to stimulate huckleberry bushes to grow faster and produce more berries.

TE-12 Retention of Brush in Clearcut Areas

Control of shrubs in clearcut areas can have adverse effects on wildlife, particularly if several adjacent clearcuts are treated simultaneously. It is the Terrestrial Habitat Panel's view that any treatment program should be designed to maintain some habitat for wildlife in brushfields.

TE-13 Limit on Chip Depth

An area uniformly covered by a 1-inch thickness of wood chips had an adverse effect on establishment of grass seeds (Rothacher and Lopushinsky 1974, p. D-7). This effect has also prevented establishment and survival of tree seedlings, shrubs, and herbaceous plants. If the chips are mulched into the soil, the carbon-nitrogen ratio causes reduced growth or death (Garrison and Smith 1974, p. P-5). Fowler (1974, p. N-12) has shown that there is a negative exponential relationship between pine and spruce seedlings and litter depth. Therefore, the Terrestrial Habitat Panel concludes that chip depth should be limited to 1 inch.

TE-14 Movement of Animals in Windrowed Residues

Terrestrial Habitat Panel members have observed forced trailing of both livestock and big game animals due to windrowed materials. Their consensus is that 200 feet between breaks in windrows is a reasonable travel distance for animals and a reasonable criterion to administer. An important consideration in windrowing material, particularly on west-side clearcuts is to avoid blocking access to streams or other water. When windrows are placed on the contour, a long, nearly impenetrable barrier between forage areas and water can result if such breaks are not provided.

TE-15 Snags

Forestry practices involving removal of dead and cull trees create changes in the forest environment which reduce both numbers and diversity of birds and mammals. The most important single effect of snag removal is the severe reduction or elimination of the opportunity for cavity nesting species to breed and successfully rear young (Cowley 1971; Haapanen 1965, 1966; Hilden 1965; Goodrum 1971).

Bertrand and Scott (1971) list 44 species of birds as preferring conifer habitat. Thirteen, or 30 percent of these species, require cavities for nesting. Elimination or reduction of species and bird numbers of this magnitude can create significant changes in the insect balance of the conifer ecosystem. Most of the species that would be eliminated or reduced are heavy insect consumers. They include chickadees, woodpeckers, bluebirds, creepers, nuthatches, titmouse, and purple martin. Insect-feeding birds are one of several natural controls which restrict the population of forest insects. Workers studying the effects of avian predation on injurious insects generally conclude that birds are normally not able to control an insect epidemic, and that birds play an important role in preventing or extending the period between epidemic insect outbreaks by continuous and effective predation on endemic populations (Bruns 1960; Otvos 1965; MacLellan 1958, 1959).

Bruns (1960) points to a number of studies which substantiate that bird densities can be increased 5 to 20 times with the addition of nest boxes; and that insect populations and forest damage are much lower where bird populations have been increased. Much of the need for nest boxes in Europe has developed from intensive silvicultural practices which require removal of dead and cull trees. Forestry practices in the Pacific Northwest are also rapidly depleting snags for the stated purposes of decreasing fire hazard and improving safety conditions for woods workers. Both purposes are legitimate; however, the forest manager often has the responsibility for maintaining habitat for all forms of wildlife and should encourage birds as a major insect predator.

Consensus of the Terrestrial Habitat Panel was that a minimum of four snags per acre be left within a cutting area; this is based on findings by Gale.[44/] He studied the use of snags for feeding and nesting in several forest types, and found that bird use varied from 0.8 to 4.3 snags per acre.

[44/] Robert M. Gale. Snags-chainsaws and wildlife. Paper presented to 4th Annual Joint Conference, American Fisheries Society, The Wildlife Society, North Lake Tahoe, Calif., 1973.

The fact that a snag does not exhibit evidence of bird use at the time of inspection should not be used as sole criterion in judging its value. The age of the snag and its potential for future use should also be considered. Gale[44/] measured several snag parameters in relation to bird use and established criteria for determining snags that provide optimum nesting or feeding habitat. He found that the value of a snag for bird nesting and feeding increases in relation to a combination of its size (both height and diameter) and softness. The ideal nesting snag should "be soft or rotten, be 20-49 feet tall, be greater than 15 inches in diameter, have the bark absent, and limbs absent or reduced to stubs." For feeding, the snag should "be soft or rotten, have a diameter greater than 15 inches, and be absent of bark."

The exceptions to the guideline statements calling for leaving snags are a result of deliberations between the Chairmen of the Terrestrial Habitat and Fire Management Panels and reflect agreement of the Public Land Management Decisions Panel. These exceptions are founded in a need to protect the forest from wildfire for overall environmental protection (see FI-8, p. 186; FI-9, p. 187; and FI-10, p. 189).

TE-16 Cull Trees

Cull trees may or may not be currently good wildlife habitat. However, the Terrestrial Habitat Panel's viewpoint is that retention of one cull tree per acre is essential if a future supply of snags and stubs is to be assured. Dominant crown position of cull trees was specified for enhancement of eagle, osprey, and other raptor habitat. The exception related to cull trees has the same basis as discussed under TE-15 above.

WA--WATER QUALITY AND AQUATIC HABITAT GUIDELINES SUPPORTING INFORMATION

WA-1 Protection of Stream Channels

Removing natural residue may seriously damage the stream channel. In many cases, natural residue provides excellent habitat for fish and should be left in place if possible (Brown 1974, p. E-8). A few logs buried in the bottom of the streambed frequently result in small waterfalls or plunge pools which increase living space and reaerate the water. Greater accumulations of large residues may act as a barrier to fish and may cause streambank erosion (Brown 1974, p. E-7).

WA-2 Removal of Unstable Residues

Residues which move and accumulate behind large obstructions cause temporary damming. Under extreme high flows, these dams break and flush out the stream channel with damage to streambanks and to fish habitat, particularly downstream from the original occurrence (Brown 1974, p. E-7).

WA-3 Prevention of Residues in Streams

Under Federal and State pollution control laws, streams may not be used for the disposal of solid wastes. Buffer strips, directional felling, cable-assisted felling, and yarding away from streams will normally keep man-caused debris out of streams (Brown 1974, p. E-4 and E-5).

WA-4 Removal of Residues with Minimum Disturbance

Optimums exist for remedial work to remove residues from streams. For example, optimum timing would be during the low water period; the optimum method of removal would be to lift residues out of the stream channel and place them well above high water. The least desirable removal method would be use of vehicular equipment in the stream channel.[45]

WA-5 Streambank Erosion From Residues

Residues such as logs or limbs over 3 inches in diameter and 5 feet long may divert water, causing erosion of streambanks (Brown 1974, p. E-7).

WA-6 Effect on Dissolved Oxygen

Fine residues (needles and twigs) in combination with low flows in small streams and with elevated water temperatures can reduce dissolved oxygen to levels unacceptable for fish habitat (Brown 1974, p. E-6). Additionally, free-flowing streams will be reaerated naturally, thus eliminating most dissolved oxygen problems (Lantz 1971).

WA-7 Mortality of Salmon Embryos

Natural conditions for salmon embryos developing in gravel are often suboptimal at best. The clogging of gravels with small amounts of fine residues can increase embryo mortality (Brown 1974, p. E-7).

WA-8 Acceptance of Federal and State Standards

The Water Quality and Aquatic Habitat Panel accepts the Federal and State standards cited in guidelines 1.905, 1.906, 1.953, and 1.954 as the best available.

WA-9 Role of Riparian Vegetation Shade

Direct sunlight provides the major source of energy for heating streams. Streamside vegetation provides shade essential to keeping water temperatures at acceptable levels for fish habitat on most small streams (Brown 1974, p. E-10).

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[45] Melvin H. Burke, "M-Watersheds," general memorandum to R. W. Lindstedt, on file, Pacific Northwest Region, USDA Forest Service, Portland, Oregon, 1965.

Widths of leave strips for shade.--On very small streams, brush is often sufficient to provide necessary shade (Brown 1974, p. E-10). Measurements along streams in western Oregon indicate that greater than 30-foot widths of uncut strips of timber along streams are not important to water temperature (Brown and Brazier 1972).

WA-10 Introduced Chemicals

Introduced chemicals used in treating forest residues and the introduced chemicals which may interact with forest residues are fertilizers and fire retardants, and pesticides (Moore and Norris 1974, p. C-15). In the fertilizer and fire retardant category, though there is an absence of direct data (Moore and Norris 1974, p. C-17), the primary water quality-related interactions with residues are presumed to be increased nutrient availability and more rapid decomposition of forest residues. In the pesticide category, the charcoal from burned forest residues may tightly adsorb applied pesticides, and any treatment drastically changing the native soil organic matter will influence pesticide retention and transport behavior (Moore and Norris 1974, p. C-19).

Guideline statements, other than 1.906, 1.954, and 1.955, do not address themselves directly to maintenance of water quality by limiting amounts of nonintroduced chemicals; other statements were directed at preventing chemical introduction from such sources as accelerated chemical leaching from stored nutrients, which may be expected with any removal of the forest floor and accompanying reduction of nutrient retention capability (Moore and Norris 1974, p. C-11), and the increase in quantity of chemicals in streams when rate of decomposition of residues exceeds the uptake by vegetation and the exchange capacity of the soil (Rothacher and Lopushinsky 1974, p. D-17). Members of the two Land Management Decisions Panels believe, however, that the behavior of nonintroduced chemicals will be adequately recognized by individuals applying these statements so that the details of "class of stream," "order of stream," "treatment method and intensity," etc., need not be spelled out in statements presented here. The following example illustrates the type of recognitions expected to be applied: In some streams draining immediately from areas of broadcast burning, temporary increases in concentrations of combustion product chemicals (sometimes above water quality standards) may be expected in proportion to the portion of the watershed that has been burned (Rothacher and Lopushinsky 1974, p. D-16). From this, it follows that downstream water quality can be maintained by limiting the extent of area burned to an equivalency of the dilution expected from conjoining waters of burned and unburned portions of the watershed.

Of greatest importance in application of chemicals is the prevention of drift or the avoidance of direct application to water surfaces. Buffer strips of untreated area along watercourses, as well as proper selections of formulations and equipment to minimize vapor loss, make this prevention possible (Norris and Moore 1971).

WA-11 Role of Riparian Vegetation and Litter in Reducing Erosion

Vegetation and litter along stream margins can be expected to reduce erosion by cushioning the impact and reducing the overland flow from precipitation as well as by providing holding material along streambanks (Burns 1970, Young and Wiersma 1973).

WA-12 Insects as Food for Fish Dependent on Riparian Vegetation

Removal of streamside vegetation may reduce the numbers and variety of insects. Insects dropping from overhanging vegetation are an important food source for fish (Brown 1974, p. E-10).

WA-13 Sediment

Sediment in streambed gravels reduces movement of water, impairs development of salmonid embryos, and restricts movement of young fish out of the gravel (Brown 1974, p. E-9).

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Glossary

available fuel - the portion of the total fuel that would actually burn under various specified conditions.

blow-out - a hollow excavated by the wind in loose soil; e.g., in sand dunes.

broadcast burning - intentional burning in which fire is set to spread over all of a specified area, usually in nonpiled fuels. In the Pacific Northwest, usually confined to burning of logging slash after clearcutting of an area.

characteristic landscape - the naturally established landscape within a scene or scenes being viewed.

coarse-textured soil - includes sands, loamy sands, and sandy loams except the very fine sandy loam textured classes. Compare fine-textured soil, medium-textured soil.

contrast - diversity of adjacent parts, as in color, tone, or emotions. the closer the juxtaposition of two dissimilar perceptions, in time or space, the more powerful the appeal to the attention.

crop tree - any tree forming, or selected to form, a component of the final crop.

cull - a tree or log of merchantable size but classified as unmerchantable because of poor form, rot, or other defect.

damping off - the rotting of seedlings, before or soon after emergence, by soil fungi attacking at soil level.

duff - forest litter and other organic debris in various stages of decomposition, on top of the mineral soil, typical of coniferous forests in cool climates where rate of decomposition is slow and litter accumulation exceeds decay.

established sapling - a young tree typically 2- to 4-inch diameter at breast height, growing vigorously and without dead bark or more than an occasional dead branch.

established seedling - a healthy, vigorous seedling that has survived for at least 2 years on the site.

evident contrast - exceptions to form, line, color, or texture infrequently found in the surrounding characteristic landscapes; or changes in existing natural character apparent to the casual forest visitor.

fine-textured soil - predominating in fine fractions, as fine clay. Includes all clay loams and clays. Compare coarse-textured soil, medium-textured soil.

fire whirl - a spinning, vortex column of ascending hot air and gases rising from a fire and carrying aloft smoke, debris, and flame. Fire whirls range from a foot or two in diameter to small tornadoes in size and intensity. They may involve only a hot spot within the fire area or the entire fire.

forest residue - the unwanted accumulation in the forest of living or dead, mostly woody material that is added to and rearranged by man's activities such as forest harvest, cultural operations, and land clearing. Forest residue includes slash materials, excessive litter on the forest floor, unwanted living brush and weed trees, and standing dead trees and snags.

fuel break - a strategically located strip or block of land of varying width, depending on fuel and terrain, in which fuel density has been so reduced as to provide an accessible location from which fires burning into it may be more readily stopped. If forested, the stand is thinned and remaining trees are pruned to remove ladder fuels; most brush, heavy ground fuels, snags, and dead trees are removed, and an open parklike appearance established in contrast to a firebreak from which all vegetation is removed.

litter - the surface layer of the forest floor consisting of freshly fallen leaves, needles, twigs, stems, bark, and fruits. This layer may be very thin or absent during the growing season.

live stream - see perennial stream.

low-speed travel - travel on established trails or roads at speeds of less than 30 miles per hour.

medium-textured soil - intermediate between fine-textured and coarse-textured soils. Includes very fine sandy loams, loam, silt loam, and silt-textured classes.

modification - a visual quality objective meaning man's activity may dominate the characteristic landscape but must, at the same time, utilize naturally established form, line, color, and texture. It should appear as a natural occurrence when viewed in foreground or middle ground.

partial retention - a visual quality objective which, in general, means man's activities may be evident but must remain subordinate to the characteristic landscape.

perennial stream - a body of continuously flowing water in a natural channel.

planting spot - an area 3 feet in diameter cleared of all residue under 3 inches in diameter and 3 feet long, and cleared to mineral soil.

prescribed burning - controlled application of fire to wild land fuels in either their natural or modified state, under such conditions of weather, fuel moisture, soil moisture, etc., as allow the fire to be confined to a predetermined area and at the same time to produce the intensity of heat and rate of spread required to further certain planned objectives of silviculture, wildlife management, grazing, fire-hazard reduction, etc.

preservation - a visual quality objective providing for ecological change only.

rate of spread - the relative activity of a fire in extending its horizontal dimensions. It may be expressed as rate of increase of the perimeter, as rate of forward spread of the fire front, or as rate of increase in area.

residue - see forest residue.

resistance to control - the relative difficulty of constructing and holding a control line, as affected by fire behavior and difficulty of line construction.

retention - a visual quality objective which, in general, means man's activities are not evident to the casual forest visitor.

sapling - see established sapling.

seedling - generally, a young tree, shrub, etc., grown from seed, from its germination up to the sapling stage (see established sapling).

shaded fuel break - see fuel break.

slash - a complex of woody forest debris left on the ground after logging, land clearing, thinning, pruning, brush removal, or natural processes such as ice or snow breakage, wind, and fire. Slash includes logs, chunks, bark, branches, tops, uprooted stumps and trees, intermixed understory vegetation, and other fuels.

smoke episode - a period when smoke is dense enough to be an unmistakable nuisance.

smoke management - a system whereby current and predicted weather information pertinent to fire behavior, smoke convection, and smoke plume movement and dispersal is used as a basis for scheduling the location, amount, and timing of burning operations. Objective is to minimize total smoke production and assure that smoke does not contribute significantly to air pollution.

snag - a standing dead tree or standing portion at least 20 feet tall from which at least the leaves and smaller branches have fallen. Often called a stub if less than 20 feet tall.

stub - a standing section of the stem of a tree, broken off at a height of less than 20 feet, from which the leaves and most of the branches have fallen. Note: For the purpose of bird habitat, the Terrestrial Habitat Panel specifies in statement 3.817 that the stub need only be less than 12 feet in height.

underburning - prescribed burning with a low intensity fire in activity-created or natural fuels under the timber canopy.

visually subordinate - less than or below another feature in visual contrast in size, color, intensity, or brightness.

wander through - areas subject to close observation via foot travel and, in some cases, horse travel.

wilderness - an area established by the Federal Government and administered either by the Forest Service of the U.S. Department of Agriculture; or the National Park Service, the Fish and Wildlife Service, or the Bureau of Land Management, all of the U.S. Department of the Interior. Objective is to conserve its primeval character and influence for public enjoyment, under primitive conditions, in perpetuity.

wildfire - an unplanned fire not being used as a tool in forest protection or management in accordance with an authorized permit or plan and which requires suppression.

Appendix 1. Acknowledgments

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Appendix 2. Model smoke management plan for prescribed burning of forest residue[1/]

INTRODUCTION

Land managers have moderate flexibility in determining when, where, and how much of their prescribed burning, with proper fuel preparation, can usually await conditions favorable for both burning and smoke dispersion. Since burning operations require elaborate planning and, at the time of execution, involve considerable deployment of equipment and personnel, the burn must be scheduled in advance on the basis of predicted conditions described in the appropriate fire-weather forecasts.

This plan provides guidelines for air resource management to be used in conjunction with fire-weather air quality forecasts during forestry prescribed burning operations. It includes a schedule of limitations for keeping excessive forest residue smoke out of sensitive areas and procedures for minimizing smoke production and impact. The plan is based on knowledge that smoke from prescribed burning of forest residue can be:

1. Regulated by scheduling and selecting a favorable smoke plume trajectory, and

2. Manipulated by fuel preparation, selection of burning conditions, and burning procedure.

OBJECTIVE

The objectives of this plan are to minimize smoke resulting from burning of forest residues and to prevent it from being carried to or accumulating in areas sensitive to smoke. Smoke Sensitive Areas (SSA) are defined as heavy

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1/ Prepared by Air Quality Technical Panel members, Leo W. Wilson and Owen P. Cramer, Fire Prevention Director, Oregon State Forestry Department, and Meteorologist, Pacific Northwest Forest and Range Experiment Station, respectively.

population or high use areas that are susceptible to excessive accumulation of atmospheric emissions because of climatic and topographic restraints on ventilation, such as in natural basins (figs. 1 and 2). SSA boundaries may be defined in terms of the confining terrain, distance from heavy population, and with a ceiling 2,000 feet above mean terrain level. SSA's are agreed upon jointly by State forestry and State air quality control agencies.

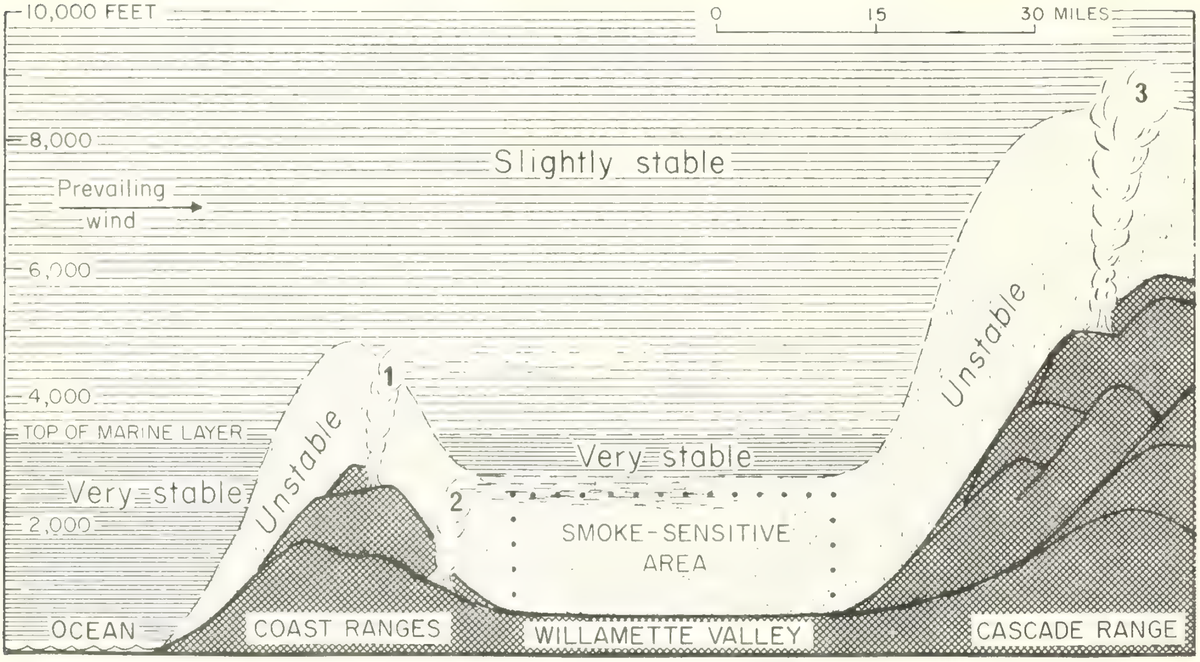

Figure 1.--Atmospheric stability conditions over western Oregon on a typical warm-season afternoon. Over the mountains the surface-heated unstable layer often extends up through the cool marine layer. A very stable layer often remains above the valley, particularly in fall, confining low-level emissions below it. (Reproduced with permission of Journal of Forestry and authors: Owen P. Cramer and Howard E. Graham, Cooperative management of smoke from slash fires, Journal of Forestry 69(6): 327-331, 1971.)

ADMINISTRATION

Each field administrator issuing permission to burn under this plan will manage the prescribed burning operations in such a way as to maintain a satisfactory atmospheric environment. To do this, he will consider weather forecasts, acreages involved, amounts of material to be burned, smoke production characteristics of fuel complex being burned, evaluation of potential smoke column vent height, direction and speed of smoke drift, residual smoke, mixing characteristics of the atmosphere, and distance from any SSA for each burning operation. He will also need to consider special situations. These are termed smoke sensitive sites which are smaller, special activity areas, such as major recreation sites, in which smoke is particularly objectionable. Here sensitivity to smoke may vary seasonally, by days of the week, with weather conditions, or may exist only for a holiday or other special occasion.

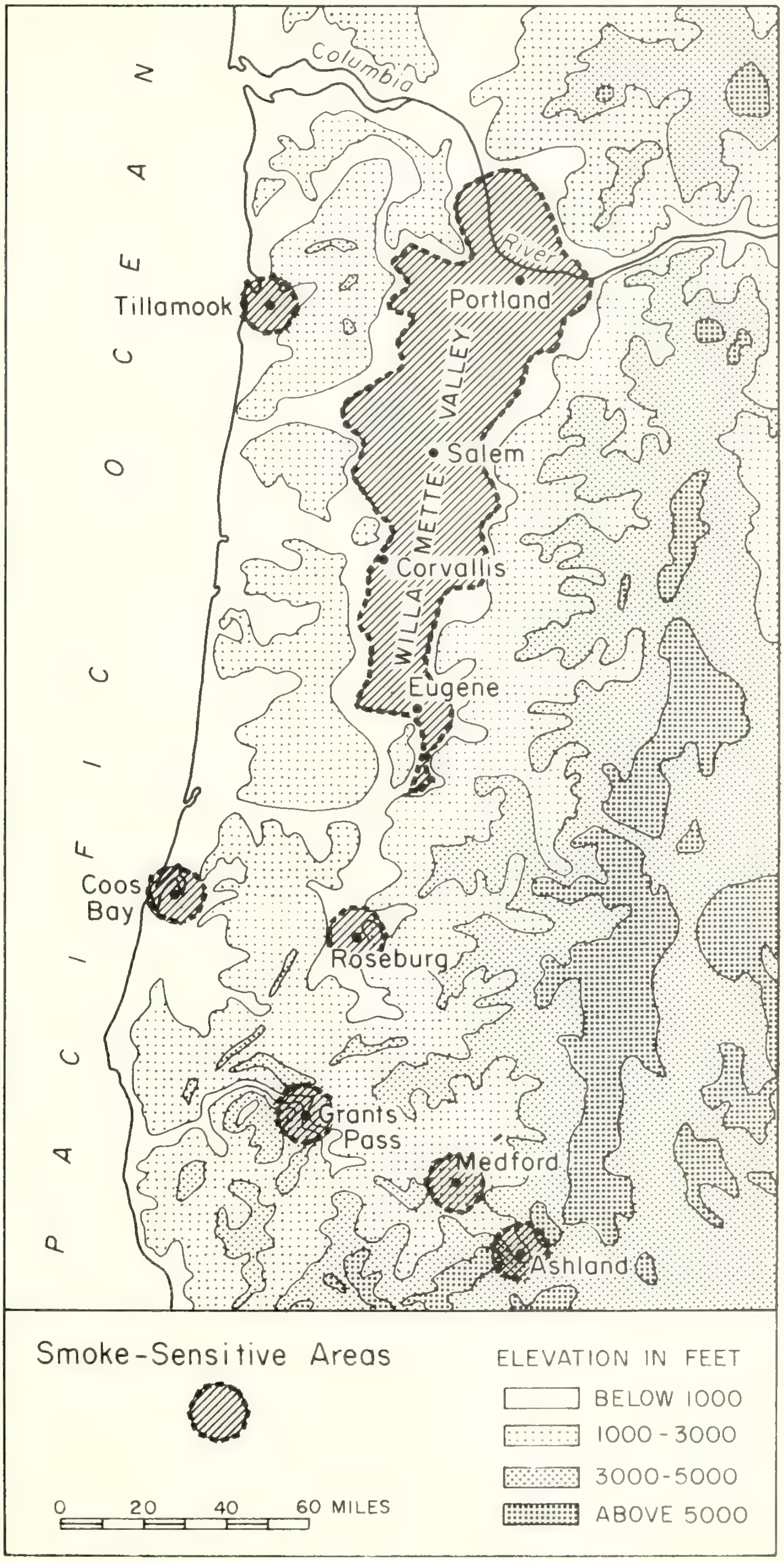

Figure 2.--Formally designated smoke-sensitive areas in Oregon included the Willamette Valley and certain urban centers. Area ceilings are generally 2,000 feet above the surface. (Reproduced with permission of Journal of Forestry and authors; Owen P. Cramer and Howard E. Graham, Cooperative management of smoke from slash fires, Journal of Forestry 69(6): 327-331, 1971.)

Each cognizant administrator will evaluate downwind conditions before starting a burn. When he determines that visibility in downwind SSA is already less than 11 miles or would likely become so with additional burning, or upon notice that air in the State, or adjacent State, or any portion thereof, is, or would likely become excessively affected by smoke, the administrator will require burning to be cancelled or terminated. Upon termination, any burning already underway will be completed as rapidly as possible and mopped up as soon as practical; and no additional burning will be attempted until favorable conditions again occur.

When residue to be burned is within 100 miles of a downwind SSA, the specific provisions of the Forest Residue Burning Restrictions for Smoke Management (p. 256) relating to quotas and smoke drift apply as well as the Procedures for Minimizing Smoke Production and Impact (p. 257). If the residue to be burned is beyond the 100-mile limit, only the more general Procedures for Minimizing Smoke Production and Impact apply.

CONCEPTS AND DEFINITIONS

The following definitions and concepts apply to this system (listed in order of decreasing importance):

air pollution - the National Air Pollution Control Administration of the U.S. Department of Health, Education, and Welfare (HEW) defined air pollution:

> Air pollution exists when contaminants are present in such quantities and of such duration as may be, or may tend to be, injurious to human, plant, or animal life, or property, or which unreasonably interferes with the comfortable enjoyment of life, or property, or the conduct of business.

smoke plume - smoke from a particular source but not in a well-defined convective column, usually with neutral buoyancy and subject to motions of the air in which it lies. Depending on the fire, it may form at the ground or at the top of a smoke convection column.

plume dispersal height or smoke venting height - the level in the vicinity of the fire at which the smoke ceases to rise and moves with the wind and turbulence acting at that level. The smoke configuration changes from a convection column to a plume at this height.

mixing height or mixed layer - height above ground to which air heated at the surface during the warm part of the day will normally rise, hence the layer through which emissions from small surface sources may be expected to mix. The mixing height is the minimum height to which a substantial smoke convection column from forest or range prescribed burning may be expected to rise.

unstable layer - characterized by turbulence and vertical motion, hence permitting convection through the layer and mixing of a plume throughout the layer. Indicated by decrease in temperature with elevation of at least 5° F per 1,000 feet. The mixed layer is an unstable layer in contact with the ground.

stable layer - turbulence and vertical motion absence; impedes ascent of convection column and prevents descent of a smoke plume aloft to lower elevation. Great range in degree of stability is possible and is most pronounced in the inversion layer--a layer through which temperature actually increases with height.

smoke plume moving away - projected plume will not intersect or pass over an SSA boundary within 100 miles downwind from the fire.

smoke plume moving toward - projected plume will intersect or pass over an SSA boundary within 100 miles downwind from the fire, or plume is within 100 miles of SSA boundary and wind direction is indeterminate due to windspeed of less than 5 mi/h at plume dispersal height.

residual smoke - smoke produced after the initial fire has passed through the fuel, usually from smoldering, incomplete combustion, and with insufficient heat or volume to produce appreciable rise.

daily quotas - actual amounts of forest residue authorized to be consumed by fire expressed as tonnage of available fuel which is expected to burn and is usually less than total fuel. Quota is also expressed in equivalent amount of particulate produced by normal burning of given amount of available fuel, assuming an emission factor of 14 lb of particulate per ton of forest residue burned. Actual emission factor varies with fuel and manner of burning.

150,000-acre administrative area - an average size fire management area here assumed as a unit area size for limiting emissions from burning operations. Burning quotas are set for unit size areas to assure some lateral spacing of resulting plumes. Indicated quotas (table 1) are for the entire 150,000-acre area. These need proportional adjustment for major differences in actual district size. For any burn situation, quotas are based on the proportion of the district within a distance class from SSA's. (For example, a 200,000-acre district would have quotas one-third greater than those in table 1. But for a given burning day, their quota for 30-60 miles from SSA would be reduced to one-tenth of the district quota if only one-tenth of the district lay within that distance class.)

no restriction - the only limit on the daily quota is the capacity of personnel and equipment to conduct a proper and safe burn and be prepared for mopup; 30,000 tons of available fuel burned per day per district is rarely exceeded.

available fuel - an estimate of the tons of fuel that will be actually consumed by fire at the given time and place. A clean broadcast burn may remove up to 75 percent of the total fuel; pile burning may remove 50 to 90 percent, depending on which fuels are piled and thoroughness of burn.

total fuel loading examples - amounts of fuel commonly found in clearcut old-growth slash west of the Cascades:

low loading--less than 75 tons per acre
medium loading--76 to 150 tons per acre
high loading--over 150 tons per acre.

test fire - small pile or small area in a broadcast burn that is ignited to confirm the burning prescription and smoke dispersal forecast before starting the burning project.

mopup - extinguishing fire, including search for and extinguishing of buried and smoldering fire remnants.

Atmospheric stability and instability and other meteorological concepts upon which this smoke management plan is based are explained in Fire Weather, 1970, by Mark J. Schroeder and Charles C. Buck, USDA Forest Service, Agriculture Handbook 360, 229 p., illus.

Dispersion conditions over Smoke Sensitive Area (SSA) and direction of drift of smoke plume	Daily quotas[1/] of forest fuels that may be consumed in each 150,000-acre administrative area (or quotas of particulate from burning these amounts--in parentheses)[2/]			
	Upwind distance from SSA boundary			
	More than 60 mi	30-60 mi	10-30 mi	Less than 10 mi
	Tons			
1. Smoke plume directly into precipitating cloud system[3/]	No restriction	No restriction	No restriction	No restriction
2. Smoke plume moving away from SSA at 5 mi/h or more	No restriction	No restriction	No restriction	No restriction
3. Smoke plume moving toward SSA[4/]				
a. Plume above stable layer and above SSA ceiling--day and night	36,000 (252)	18,000 (126)	9,000 (63)	6,000 (42)
b. Plume mixed through deep layer over SSA. Mixing level more than 1,000 feet above SSA ceiling--day only	18,000 (126)	9,000 (63)	4,500 (31.5)	3,000 (21)
c. Plume below SSA ceiling--day only	9,000 (63)	3,000 (21)	1,500 (10.5) Complete the burning of any area already afire in excess of these restrictions as rapidly as possible and mop up smoldering residual fire.[5/]	No new fires; chunk-in ongoing fires. Complete the burning of any area already afire in excess of these restrictions as rapidly as possible, and mop up smoldering residual fire.[5/]

1/ Except as noted, half of quota may also be burned at night, in addition to daytime total, where conditions are otherwise favorable. Total quota for a 1-million-acre administrative area may not exceed 150,000 tons per day under condition 3 (smoke toward SSA).

2/ Based on emission factor of 14 lb of particulate from 1 ton of forest fuel. Burning quotas may be based on particulate emission for the given fuel complex and burning method.

3/ No burning when visibility (visual range) is less than 11 mi except under condition 1.

4/ Amounts decrease for windspeeds slower than 16 mi/h at plume dispersal height: 10-15 mi/h, 75 percent of quota; 5-10 mi/h, 50 percent; under 5 mi/h, 25 percent. Plume dispersal winds of less than 5 mi/h are considered too light to be of dependable direction, hence are assumed to be toward SSA.

5/ When plume rise decreases due to deterioration of earlier, more favorable conditions.

FOREST RESIDUE BURNING RESTRICTIONS FOR SMOKE MANAGEMENT

Most of the details of residue burning restrictions for smoke management are covered in table 1. Briefly, these restrictions provide for the following:

Only limited burning is permitted when smoke will disperse in air that is moving toward a Smoke Sensitive Area within 100 miles. No burning will be permitted if the smoke will be confined to elevations below the area's specified ceiling when the burn is less than 10 miles from a sensitive area. Limited burning is permitted if the smoke will be dispersed through a deep layer extending above the SSA ceiling. Only under special conditions will unlimited burning be permitted: (1) when the smoke will blow directly away from an SSA; (2) if smoke will blow toward an SSA, when the nearest such area is no closer than 100 miles downwind; and (3) when the smoke rises into the base of a precipitating cloud system.

Other details and explanation of smoke management provisions are:

Visibility.--No burning will be permitted (no new starts) when the downwind visual range at the surface is less than 11 miles, unless such obstruction is produced by fog, precipitation, or water droplet cloud. Ten miles is equivalent approximately to the effect of suspended particulate in the amount of 75 micrograms per cubic meter (Air Quality Criteria for Particulate, HEW 1969, p. 3-19), the National Ambient Air Quality Standard for Suspended Particulate which is given as the maximum allowable annual geometric mean. A 24-hour average concentration of 260 micrograms per cubic meter, or a visual range of approximately 3.5 miles, is not to be exceeded more than once a year. The intent of the Smoke Management Plan is to maintain the visual range at no less than 10 miles at any time in Smoke Sensitive Areas due to the prescribed burning of forest residues.

Changes after firing.--Should conditions deteriorate while burning is in progress, plans for burning should be revised to correspond to amounts permissible under the new conditions. Where no burning would be permitted under the revised classification, ongoing burns should be completed quickly and, where practical and safe, fuels chunked in to permit more rapid burning.

Liaison with air pollution control officials.--Regional and State air pollution control agencies must be kept informed of burn plans, operations, and current orders. They receive inquiries about visible smoke plumes and should be kept up to date.

Fire-weather forecasts.--Each Forest or State district will maintain contact with the fire-weather forecaster of the National Weather Service, to relay weather data to the agency in charge of the burning and to arrange for special weather observations as needed.

Precipitating cloud system.--Smoke that actually disperses within a precipitating cloud system is likely to become condensation nuclei and be subjected to washout mechanisms that may remove most of it in a short time. A layer of fog or stratus from which drizzle is falling does not qualify.

Optimum dispersal winds.--Windspeeds of more than 15 mi/h have been assumed to provide the standard dilution of the smoke plume at venting height. Daily burn quotas are decreased in slower winds, which provide less dilution and slower transport of the plume.

Smoke plumes aloft.--Smoke plumes aloft that are completely separated from surface air by a stable layer do not detract from air quality at the surface and may not be readily distinguishable from normal water droplet or ice crystal clouds. Nevertheless, some limitations are imposed when such clouds are expected to pass over an SSA (condition 3a in table 1).

PROCEDURES FOR MINIMIZING SMOKE PRODUCTION AND IMPACT

Some of the practices which will assist in minimizing the impact of smoke emissions are:

1. *Weather*. Prior to ignition of the test fire, both the latest fire-weather forecast and the observed conditions at the site must indicate that smoke dispersal as well as fire behavior conditions are favorable. The test fire will help to confirm this.

2. *Time of ignition*. Selection of the correct time to burn will help to minimize the amount, dispersal, and visibility of resulting smoke.

   a. *If burning can be completed in less than 12 hours*, ignition in the morning will take advantage of the heated mixed layer above the surface. Smoke columns normally rise higher and turbulent dispersion of smoke is more rapid during the warm part of the day. However, morning ignition will not be permitted if fire-danger indexes are predicted to rise above safe levels at any time during the burnout period.

   b. *If burning requires more than 12 hours* and considerable smoldering remnants may be expected to produce residual smoke after the main burn, ignition at night may minimize drift smoke accumulation. This is effective for higher elevation, heavy fuel burns above the usual valley bottom inversions. The more stable night air is compensated for by the strong convective column phase of the burn. By the time the residual burning stage is reached, daytime heating may be only a short time away so that the low-energy stage of the burn is compensated for by the better daytime dispersion conditions.

3. *Condition of fuel*. Burning of cured or well-dried material is favored as consistent with safety and burning objectives, because it burns hotter, hence will produce less visible emission and will produce a stronger convective column reaching greater heights.

4. *Rapid firing*. The objective is to develop maximum heat energy per unit time to vent the smoke at the highest elevation possible. Prescribed burns should be fired as rapidly as safety and the objectives of the burn will permit.

5. *Preparation of fuel.* To achieve maximum flexibility in selection of time of burning and the optimum smoke dispersion conditions, it is often desirable to prepare residue for burning during the wet season. This may be done by piling or windrowing and covering with plastic to keep the fuel dry through the early fall rains. Fuel piled without soil will burn more efficiently under a much greater variety of weather conditions than fuel requiring broadcast burning. Properly cured, clean piles will also produce less holdover fire and smoldering smoke.

6. *Chunking-in.* Pushing together large pieces in a burning pile will help to maintain flaming combustion. This practice reduces the total volume of smoke, shortens mopup and patrol time, and prevents holdover fires. When conditions change after burning has been started, so that burning operations would be restricted or cancelled, fires that are chunked-in will normally produce less smoke for shorter periods than mopup work.

Appendix 3. Special analysis of known fuel break encounters

1. Name and date	2. Details on fuel break	3. Manning	4. Line construction on fuel break	5. Firing out	6. Control of spot fires beyond fuel break
ANGELES NATIONAL FOREST					
Akens Fire, 7/6/72		Yes, first attack with helitanker and 13-man crew	Existing line on fuel break	No	Some spotting, controlled due to ready access along fuel break
Bear Fire, 9/5/66					
Bouquet Fire, 9/10/64				Yes	
Devon Fire					
Dry Fire, 7/2/64	Fire lane	No			
Easley Fire, 7/12/68[2/]	Disked soil	Yes			
Loop Fire, 10/1/66[3/] Santa Clara Fuel Break					Manned quickly from fuel break
Lukens Fire, 8/26/65 Mount Lukens Fuel Break		Yes	Yes	Yes	
Morris Fire, 7/8/62 Glendora Ridge Fuel Break					3 across narrow portion were quickly extinguished
Pacoima Fire, 2/22/63					
Rabbit Fire, 7/13/67 Round Top Fuel Break					
Redrock Mountain Fuel Break, July 1968					
Tule Fire, 4/17/62					

See footnotes, p. 268.

Fuel Break Encounters

7. Success or failure	8. Reasons indicated for success or failure	9. Fuel type	10. Fire danger at encounter	11. Fire behavior at encounter
Success	Fuel break provided quick access and reduced resistance to control in grass established on the fuel break. Fuel break was final control along top of fire, approximately 2 mi.	Chaparral	Extreme temperature 93, humidity 30, fuel moisture 7	Fire spread up steep slope from bottom of canyon to top of main ridge in 1 hour (estimated distance, 60 chains)
Success	Fuel break held fire until manpower arrived at fire head	Chaparral		
Success				
Success				
Success	Unattended break held fire due to burning conditions	Chaparral		
Success	Fire stopped at fuel break except for two slopovers	Chaparral		
Success	Fuel break provided safe access	Chaparral		
Success	Personnel safety a big factor in success	Chaparral		
Success	Safe and rapid access made possible keeping fire out of town	Chaparral	Moderately severe	Rate of spread about average for conditions but intensity well above average
Success	Fuel break provided safe and rapid access to head of fire	Chaparral		
Success	Safe access	Chaparral		
Success		Chaparral		
Success	4-7 miles of a 12-mile perimeter were held by this installation	Chaparral		

1. Name and date	2. Details on fuel break	3. Manning	4. Line construction on fuel break	5. Firing out	6. Control of spot fires beyond fuel break
CLEVELAND NATIONAL FOREST					
Boulder Fire, 9/28/70 Middle Fork Fuel Break	150 ft wide, little maintenance and in "messy" condition	Yes	Truck trail on fuel break as line	In part but not a factor of success	
Boulder Oaks Fire, 10/27/73	Natural fuel break (meadow)	Yes		Yes	
Laguna Fire, 9/26/70 Corte Madera Fuel Break	Approximately 150 ft wide	Yes		Yes	1/2-mile spot fires could not be controlled
Japatul Fuel Break	Approximately 150 ft wide	Yes		No	Spot fires occurred and were not controlled
Morena Fuel Break	300 ft wide	No	No	No	
Pine Valley Fuel Break	Constructed 200-250 ft wide. Little maintenance, scattered brush and herbs	Yes	Dozer at time of use	Yes	
Meyers Fire, 10/1/70 Foothill Fuel Break	150-200 ft wide	Initially only 3 men	Road used as line	Fired with assist from upslope wind opposing gradient wind during part of firing operation	
Tecate Fire, 8/25/70 Barrett Fuel Break	200 ft wide	Yes	Used truck trail on fuel break as line	Fired into wind	Controlled by ground tanker crewmen from fuel break
International Fuel Break (5 of 40 mi total)	300 ft wide	Yes	None, but ground tanker used to provide water line in grass on fuel break	Yes	

See footnotes, p. 268.

Fuel Break Encounters (continued)

7. Success or failure	8. Reasons indicated for success or failure	9. Fuel type	10. Fire danger at encounter	11. Fire behavior at encounter
Success	Fire backed into fuel break and was easily held due to lighter fuels along break (if other than a backing fire, failure would have been possible)	Brush and coniferous timber	Santa Ana winds	Backing fire toward fuel break
Success	Light fuels permitted safe attack	Chaparral	Santa Ana winds	
Partial success	Fire not controlled due to spot fires, but it was possible to protect adjacent properties since fuel break made it safe for tankers	Chaparral	Santa Ana winds 40 mi/h	High intensity fire, main spread toward fuel break
Partial success	Fire not controlled due to spot fires, but it was possible to protect adjacent properties since fuel break made it safe for ground tankers	Chaparral	Santa Ana winds 40 mi/h	High intensity fire, main spread toward fuel break
Failure	Fire spread across fuel break in absence of manning	Chaparral	Santa Ana winds 40 mi/h	High intensity fire, main spread toward fuel break
Success (saved 30 homes)	Obvious change in fire behavior in fuels on fuel break	Chaparral	Santa Ana winds 40 mi/h	High intensity fire, main spread toward fuel break
Success	Firing out the lighter fuels (grass) made control possible, saving many expensive structures	Chaparral	Northerly winds 40-50 mi/h	Fire burning downslope with gradient wind
Success	Control of fire made possible from this fuel break	Chaparral	Santa Ana winds 40-50 mi/h	High intensity fire, main spread toward fuel break
Success	Grass fuel on fuel break permitted water lines and firing out ahead of fire	Chaparral	Santa Ana winds 40 mi/h	High intensity fire, main spread toward fuel break

1. Name and date	2. Details on fuel break	3. Manning	4. Line construction on fuel break	5. Firing out	6. Control of spot fires beyond fuel break
CLEVELAND NATIONAL FOREST (continued)					
International Fuel Break					
Julian-Sunrise Fuel Break					
Magee Fuel Break					
Pauba Fuel break					
KLAMATH NATIONAL FOREST Con Fire, 7/19/73[4/]	100 ft wide, grass covered				
Louis Fire, 10/28/68[5/] Fuel break in path of head		No		No	3 spot fires remained uncontrolled
Fuel break on east side of fire	2 years since constructed in thinned pine 12-18 ft high, with shaded grass cover which had been grazed to 4- to 6-in stubble	Little or none			
LOS PADRES NATIONAL FOREST Coyote Fire, 9/22/64					
Romero Fire, 10/6/71 Camino Cielo Fuel Break		Yes, with air tanker support	Yes		
Sisar Fire, 10/29/67[6/]		Yes, with air tanker support			Yes, with air tankers
Tunnel 10 Fire, 11/1/66		No			

See footnotes, p. 268.

Fuel Break Encounters (continued)

7. Success or failure	8. Reasons indicated for success or failure	9. Fuel type	10. Fire danger at encounter	11. Fire behavior at encounter
Numerous		Chaparral	Normally severe	
6 successes		Chaparral	Normally severe	
Success		Chaparral	Normally severe	
3 failures		Chaparral	Normally severe	
Success	Changed behavior of fire along fuel break and access to head of fire	Timber and brush		
Failure	Not manned	Lodgepole logging slash, 3- to 6-yr ponderosa pine thinning slash, unthinned pine	Winds 25-30 mi/h	Crowning
Success	As a flanking line, the fuel break effectively changed fire behavior preventing further spread eastward with little or no manning	Lodgepole logging slash, 3- to 6-yr ponderosa pine thinning slash, unthinned pine	Winds 25-30 mi/h	Crowning
Partial success	20 miles of fuel break were fired out and held but subsequently lost by being outflanked next day	Chaparral		
Success	Change in fire behavior due to modified fuels, plus access, permitted holding fire from crossing the ridge along 12 miles of fuel break	Chaparral	Extreme	
Success	Fuel break provided easy and safe access, allowing rapid and safe movement of men and equipment to strategic points. Averted a major conflagration with likely heavy loss of property	Chaparral	Extreme	High intensity
Failure	Fire crossed fuel break before initial attack crew arrived			

1. Name and date	2. Details on fuel break	3. Manning	4. Line construction on fuel break	5. Firing out	6. Control of spot fires beyond fuel break
MENDOCINO NATIONAL FOREST					
Horse Fire, 8/6/66[7/] Horse Pasture Ridge Fuel Break					
SIERRA NATIONAL FOREST					
Backbone Fire, 8/21/62	Partially completed	Yes		Yes	
Backbone Fire, 1964		Yes		Yes	
Haslett Fire, 10/15/61	Incomplete fuel break	3 men only	Yes	Yes	
Sugarloaf Fire, 7/13/64		In part and support by air tanker			Yes
Thornberry Fire, 7/21/68		Yes		Yes	
Whitener Fire, 7/10/64		12 ground tankers plus 2-man crew			
STANISLAUS NATIONAL FOREST					
Tuolumne River Fire, 7/11/68[8/] Miller Ridge Fuel Break	75-100 ft wide, grass covered	Aggressive holding action by first-in units. Air tanker support		Yes	One 1-acre spot fire
Wet Meadow Fire, 7/5/62	Newly constructed, 150-300 ft wide--mostly bare	Initially 3 men	None needed	No	

See footnotes, p. 268.

Fuel Break Encounters (continued)

7. Success or failure	8. Reasons indicated for success or failure	9. Fuel type	10. Fire danger at encounter	11. Fire behavior at encounter
Success	Fuel break helped to hold fire from crossing ridge	Mixed conifer	Very high	
Success	Firing out made control from the fuel break possible; fire was nearly lost due to outflanking slopover, but this was picked up by crews with access from the fuel break		Average burning conditions	
Success	Access and reduced fuel made firing out and use of water possible			
Success	Good access and availability to speed up firing out	Logging slash, timber, and brush	Ignition index 75 Burning index 24	Initial rate of spread 1.4 chains/hour
Partial success	Early failure when unmanned. Later, success due to manning			
Success	Controllable behavior of burnout fire in the reduced fuels on the fuel break	Timber and brush		
Success	Access and firing out in grass fuel on fuel break	Grass and chaparral	Wind 12 mi/h	
Success	Safe access and reduced fuels	Mixed brush	High	
Success	Permitted safe access and prevented fire from crossing ridge	Timber and brush	Moderate	No unusual fire behavior

Footnotes for appendix 3

1/ The information presented in this appendix was obtained from various sources, mainly by personal conversation with people directly involved with the fires. If further details are desired, write to Fire Management on the National Forest on which the fire occurred.

2/ The fuel break insured greater maneuverability of men since they could be placed directly in front of the fire and moved about without any great danger to themselves. This safety factor alone insures a greater effectiveness in placement and distribution of men to rapidly and efficiently suppress running fires.

3/ Without the presence of the Santa Clara fuel break, keeping the fire on the south side of the Los Pinetos ridge would have been impossible. The fuel break provided safe access along the ridge and even though spots occurred in the grass on the break and in the brush on the north side, the firefighters were able to jump on them fast and control them.

4/ The Con Fire burned 13 acres and would have been larger except that it ran into a fuel break that was constructed in 1966 and drilled with grass. This break was at the head of the fire which allowed crews to concentrate their efforts on both flanks.

5/ When the crown fire hit the fuel break, it came to the ground. This is still evident in the fire area as the fuel break still has green trees along its total length. Two tanker crews could have held this fire along the front, if they had been available. The three or four spot fires across the break would have been easily picked up by these crews.

6/ Key points in control of the Sisar Fire under extreme weather conditions were:

a. Access provided by the Ojai Front Country fuel break.
b. Relatively safe environment created by the fuel break which allowed rapid deployment of men and machines at all strategic points on the fire perimeter.
c. Relatively light fuel on the fuel break which increased effectiveness of the air tankers.
d. Strong, sustained air attack from time of first dispatch. (First dispatch--one B-17, one TBM, two F7F's, which were supported later by the addition of two more TBM's and one B-17, making a total of seven air tankers dropping on the fire.)
e. Strong initial dispatch of conventional fire forces (four districts in Los Padres, Ventura County Fire Department, and California Division of Forestry, and other mutual aid equipment).
f. Ready availability of dozers due to extreme fire weather alert.

7/ The existence of a fuel break on Horse Pasture ridge was effective in controlling the fire. It is estimated that without this improvement this fire had the potential to burn an additional 10,000 acres in Thatcher Creek. This fuel break is positive evidence that costs in constructing this type of improvement can be justified and that fuel breaks are effective in fire suppression even under adverse burning conditions.

8/ It was generally felt that had not the fuel break been in existence on Miller ridge, Forest Service protected area burned could have been materially greater. The combination of quick dispatch and utilization of ground pumpers on the fuel break access road held the fire at ridgeline and enabled full effort to be put on the flanks of the fire.

Appendix 4. Metric conversion table

1 inch	= 2.54 centimeters
0.3937 inch	= 1 centimeter
1 foot	= 0.3048 meter
3.281 feet	= 1 meter
1 cubic foot	= 0.02832 cubic meter
35.31 cubic feet	= 1 cubic meter
1 square foot	= 0.0929 square meter
10.76 square feet	= 1 square meter
1 acre	= 0.4047 hectare
2.471 acres	= 1 hectare
1 mile	= 1.609 kilometers
0.622 mile	= 1 kilometer
1 ton (short)	= 0.907 ton (metric)
1.102 tons (short)	= 1 ton (metric)
1 ton (short) per acre	= 2.241 tons (metric) per hectare
0.446 ton (short) per acre	= 1 ton (metric) per hectare
1 inch per foot	= 8.333 centimeters per meter
0.120 inch per foot	= 1 centimeter per meter
1 pound per square inch	= 70.31 grams per square centimeter
0.014 pound per square inch	= 1 gram per square centimeter

Appendix 5. List of plant and animal species cited

The sources for the scientific names are Little (1953) for trees and plants except huckleberry, oxalis, salmonberry, and swordfern, which are taken from Peck (1961), Peterson (1961) for birds, Blickenstaff (1970) for insects, Ingles (1965) for mammals, and American Fisheries Society (1960) for fish. No common names are given for diseases except for mistletoe and dwarf mistletoe which are from Boyce (1961).

TREES AND PLANTS

bigleaf maple	*Acer macrophyllum* Pursh
bitterbrush	*Purshia* spp.
California black oak	*Quercus kelloggi* Newb.
canyon live oak	*Quercus chrysolepis* Liebm.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Engelmann spruce	*Picea engelmannii* Parry
golden chinkapin	*Castanopsis chrysophylla* (Dougl.) A. DC.
grand fir	*Abies grandis* (Dougl.) Lindl.
huckleberry	*Vaccinium* spp.
incense-cedar	*Libocedrus decurrens* Torr.
juniper	*Juniperus* spp.
lodgepole pine	*Pinus contorta* Dougl.
mountain ash	*Sorbus* spp.
mountain hemlock	*Tsuga mertensiana* (Bong.) Carr.
noble fir	*Abies procera* Rehd.
Oregon white oak	*Quercus garryana* Dougl.
oxalis	*Oxalis oregana* Nutt.
Pacific dogwood	*Cornus nuttallii* Audubon
Pacific madrone	*Arbutus menziesii* Pursh
Pacific silver fir	*Abies amabilis* (Dougl.) Forbes
ponderosa pine	*Pinus ponderosa* Laws.
Port-Orford-cedar	*Chamaecyparis lawsoniana* (A. Murr.) Parl.
red alder	*Alnus rubra* Bong.
redwood	*Sequoia sempervirens* (D. Don) Endl.
salmonberry	*Rubus spectabilis* Pursh.
Shasta red fir	*Abies magnifica* var. *shastensis* Lemm.
Sitka spruce	*Picea sitchensis* (Bong.) Carr.
subalpine fir	*Abies lasiocarpa* (Hook.) Nutt.
sugar pine	*Pinus lambertiana* Dougl.
swordfern	*Polystichum munitum* (Kaulf.) Presl
tanoak	*Lithocarpus densiflorus* (Hook & Arn.) Rehd.
vine maple	*Acer circinatum* Pursh.
western hemlock	*Tsuga heterophylla* (Raf.) Sarg.

western juniper	*Juniperus occidentalis* Hook.
western larch	*Larix occidentalis* Nutt.
western redcedar	*Thuja plicata* Donn
western white pine	*Pinus monticola* Dougl.
white fir	*Abies concolor* (Gord. & Glend.) Lindl.

INSECTS

balsam woolly aphid	*Adelges piceae* (Ratzeburg)
Douglas-fir beetle	*Dendroctonus pseudotsugae* Hopkins
mountain pine beetle	*Dendroctonus ponderosae* Hopkins
pine engraver beetle	*Ips pini* (Say)
spruce bark beetle	*Dendroctonus obesus* (Mannerheim)
western pine beetle	*Dendroctonus brevicomis* LeConte

DISEASES

	Armillaria mellea
	Fomes annosus
	Phytophthora lateralis
	Poria weirii
dwarf mistletoe	*Arceuthobium* spp.
mistletoe	*Phoradendron* spp.

BIRDS

bluebird	*Sialia* spp.
chickadee	*Parus* spp.
creeper	*Certhia* spp.
eagle	Buteoninae (family)
nuthatch	*Sitta* spp.
osprey	*Pandion haliaetus*
purple martin	*Progne subis*
titmouse	*Parus* spp.
woodpecker	Picidae (family)

FISH

salmon	*Oncorhynchus* spp.

MAMMALS

brush rabbit	*Sylvilagus bachmani*
deer mouse	*Peromyscus maniculatus* (Wagner)
snowshoe hare	*Lepus americanus*

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1961. A field guide to western birds. 366 p., illus. Boston: Houghton Mifflin Co.

Appendix 6. User's work form

Project name or other identifiers:

Administrative unit name or other identifiers:

USER'S WORK FORM

GUIDELINES FOR FOREST RESIDUES MANAGEMENT

This form has been developed to help users sort for guideline statements believed to apply to specified land management situations. It is intended for use with the publication:

> Pierovich, John M., Edward H. Clarke, Stewart G. Pickford, and Franklin R. Ward. 1975. Forest residues management guidelines for the Pacific Northwest. Pacific Northwest Forest and Range Experiment Station USDA Forest Service General Technical Report PNW-33.

STEP 1 Enter the information requested in Input Blocks 1 through 5 of this form.

Input Block 1

This work form applies to (circle only one):

PUBLIC LAND PRIVATE LAND

STEP 2

PUBLIC LAND ↓	PRIVATE LAND ↓
Open Guidelines publication to chapter II, Table Set I (yellow paper)	Open Guidelines publication to chapter II, Table Set II (pink paper)

Input Block 2

This work form applies to (check only one):

____ A. Road construction
____ B. Trail construction
____ C. Campground construction
____ D. Structure construction
____ E. Ski run construction
____ F. Utility right-of-way construction
____ G. Timber harvest by individual tree selection cutting
____ H. Timber harvest by shelterwood cutting
____ J. Timber harvest by group selection cutting
____ K. Timber harvest by clearcutting
____ L. Precommercial thinning
____ M. Commercial thinning
____ N. Type conversion, except rangeland
____ O. Treatment of natural residue
____ P. Treatment of dying and damaged vegetation
____ Q. Rangeland type conversion

USER'S WORK FORM (Cont.)

STEP 3 Within the Table Set (I or II) chosen in Step 2, turn to the Sorting Set letter corresponding to the letter checked in Input Block 2. Note that there are either four or five tables within this Sorting Set. Refer to Table 1 now and list all statement numbers shown in the box below:

Statement List 1 (from Table 1):

Input Block 3

This work form applies (circle only one):

where residues will or may be burned	where residues will not be burned

STEP 4 If residues will be or may be burned, refer to Table 2 now and list the statement numbers shown in the box below:

If residues will not be burned, check here and proceed to step 5----- ☐

Statement List 2 (from Table 2):

USER'S WORK FORM (cont.)

STEP 5 If Input Block 4 is for Private Land, check here and go to Step 6 - ☐

If Input Block 4 is for Public Land and the notation "Skip Table 3" is circled in Input Block 4, check here and go to step 6 - - - - - - - - ☐

If Input Block 4 is for Public Land and a column number is circled in Input Block 4, enter the column number in the space labeled "from Table 3, column ____" in the box below. Find this column number in Table 3 and enter all the statement numbers found there in the box below.

Statement List 3 (from Table 3, column ____).

Input Block 4

This work form will be for (circle only one):

Public Land

If for public land, proceed to trace from left to right along the path describing the visual management classification for your project. Circle only the column number indicated.

Private Land

If for private land, skip this block and check here: ______

Column numbers

- Public Land
  - Area not formally classified under visual management system → 1
  - Area formally classified under visual management system
    - Area classified as foreground
      - Area designated for modification
        - Occupancy & wander-through are main use patterns → 2
        - Low-speed pass-by is main use pattern → 3
        - High-speed pass-by is main use pattern → 4
      - Area designated for partial retention
        - Occupancy & wander-through are main use patterns → 5
        - Low-speed pass-by is main use pattern
          - Little or no screening → 6
          - Moderate to heavy screening → 7
        - High-speed pass-by is main use pattern
          - Little or no screening → 8
          - Moderate to heavy screening → 9
      - Area designated for retention
        - Occupancy & wander-through are main use patterns → 10
        - Low-speed pass-by is main use pattern
          - Little or no screening → 11
          - Moderate to heavy screening → 12
        - High-speed pass-by is main use pattern
          - Little or no screening → 13
          - Moderate to heavy screening → 14
      - Area designated for preservation → 15
    - Area classified as middle ground
      - Area designated for modification → 16
      - Area designated for partial retention → 17
      - Area designated for retention → 18
      - Area designated for preservation → 19
    - Area classified as background → (Skip Table

Input Block 5

a. Refer to the Forest Residue Type Area maps in the Guidelines publication (chapter II, Figure 1 or 2), and locate the type area for which this work form applies. Enter here the five-digit code for this area below:

		: Timber Spp. Assoc.			
:	:	:	:	:	:
:	:	:	:	:	:
: Province		:	: Subprovince		

b. Refer to the Forest Residue Type Area discussion (Guidelines publication, chapter II). Using your knowledge of the specific area for which this worksheet applies, review the descriptions of the Timber Species Associations and of those geomorphic subprovinces, within your province, for accuracy. Because the Forest Residue Type Area map must be somewhat generalized, you may find a description which better fits your situation.

After your review, enter below a final, confirmed (from part a, above), or revised identifying number.

(CAUTION - use only Subprovince numbers and Timber Species Associations numbers listed as "recognized" for your province):

		: Timber Spp. Assoc.			
:	:	:	:	:	:
:	:	:	:	:	:
: Province		:	: Subprovince		

USER'S WORK FORM (cont.)

STEP 6 Enter the Province number (first two digits in part b of Input Block 5, above) in the space labeled "from Table 4, column ____" in the box below. Then list all statement numbers in this column of Table 4 in the box below.

Statement List 4 (from Table 4, column ____):

STEP 7 For some management activities, there will be a Table 5. If there is no Table 5 in your sorting set, check here and go to step 8 - ☐

If there is a Table 5, refer back to Input Block 3.

If residues will not be burned, check here and go to step 8 - ☐

If residues will be or may be burned, enter the Province number (first two digits from Input Block 5) in the space labeled, "Table 5, column ___," in the box below.

In the box below, list all statement numbers shown in that column.

Statement List 5 (from Table 5, column ____):

USER'S WORK FORM (cont.)

STEP 8 If you are using Table Set I, for public lands, turn to Table Set IA (blue paper). If you are using Table Set II, for private lands, turn to Table Set IIA (green paper).

STEP 9 Use the Province number (first two digits from Input Block 5), to locate in your Table Set the appropriate tabulation of statement numbers for your Province.

STEP 10 Within this Province, find the Timber Species Association identifying number (third digit, part b, of Input Block 5). These rows of statement numbers apply to your Timber Species Association. Then use the Subprovince identifying number (last two digits from part b of Input Block 5), to locate the column for your Subprovince.

Use this column and these rows to verify the applicability of statement numbers in Statement Lists 4 and 5. ONLY THE STATEMENT NUMBERS LISTED PREVIOUSLY IN LISTS 4 AND 5 AND THEN FOUND AGAIN HERE ARE VERIFIED. CROSS OUT ALL STATEMENT NUMBERS IN LISTS 4 AND 5 WHICH ARE NOT VERIFIED.

STEP 11 You now have a complete set of Statement numbers (from Lists 1 through 5) which should be applicable to most situations like the one for which you have prepared this form. Use these numbers to locate the actual statements listed in chapter III, p. 135-157, for Public Lands and in chapter III, p. 160-172, for Private Lands. You will want to note carefully all EXCEPTIONS to any statement to determine if your situation may be one for which a certain guideline was not intended to apply.

You may wish to attach to this form a record of departures from recommended guidelines, as well as any other notes regarding modifications or limits you may develop. In this way, this work form and attachments will be available for future reviews of the decisions you have made regarding forest residues management.

☆ U S GOVERNMENT PRINTING OFFICE 1975—698-722 /178 REGION 10

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

Fairbanks, Alaska
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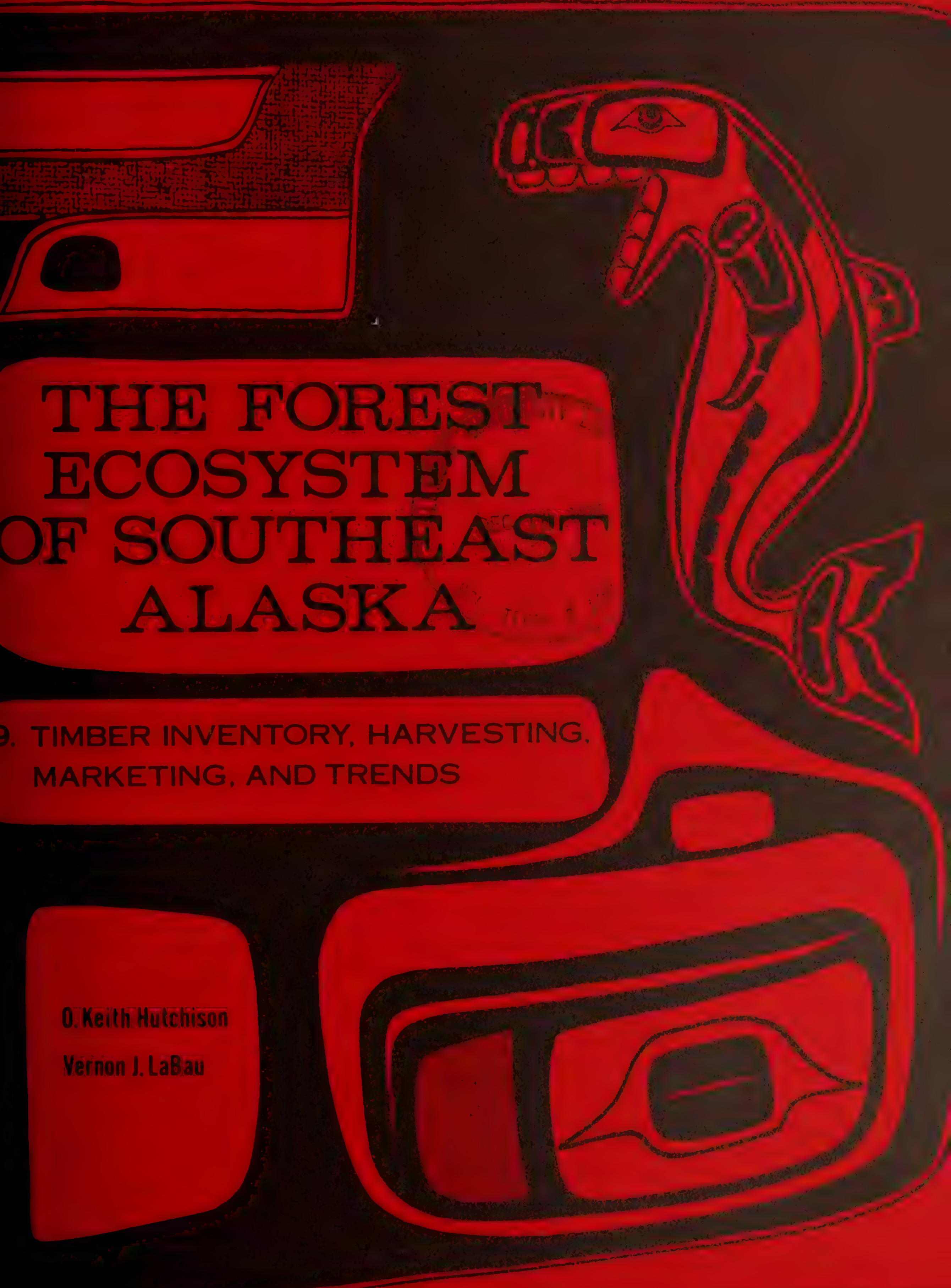
Portland, Oregon
Olympia, Washington
Seattle, Washington
Wenatchee, Washington

Mailing address: Pacific Northwest Forest and Range Experiment Station
P.O. Box 3141
Portland, Oregon 97208

USDA FOREST SERVICE GENERAL TECHNICAL REPORT PNW



THE FOREST ECOSYSTEM OF SOUTHEAST ALASKA

9. TIMBER INVENTORY, HARVESTING, MARKETING, AND TRENDS

O. Keith Hutchison

Vernon J. LaBau

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATIO
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVI

ABSTRACT

Southeast Alaska has 11.2 million acres of forest land, of which 4.9 million acres are considered commercial. This commercial acreage supports 166 billion board feet of sawtimber. These primarily old-growth stands of Sitka spruce and western hemlock are supporting a growing wood products industry that ranks first in the southeast economy and third in the State.

This report summarizes current knowledge of the timber resource (areas, volumes, growth, mortality, quality, productivity, and trends) from the initial inventory, a partial remeasurement, and a second inventory now in progress. Historical data of wood products use, output, value, and markets are given and discussed.

The report gives sources for much published and unpublished information for those who need to pursue these subjects more completely.

Keywords: Resources (forest), timber operations (general), timber marketing.

PREFACE

This is the ninth in a series of publications summarizing knowledge about the forest resources of southeast Alaska.

Our intent in presenting the information in these publications is to provide managers and users of southeast Alaska's forest resources with the most complete information available for estimating the consequences of various management alternatives.

In this series of papers, we will summarize published and unpublished reports and data as well as the observations of resource scientists and managers developed over years of experience in southeast Alaska. These compilations will be valuable in planning future research on forest management in southeast Alaska. The extensive lists of references will serve as a bibliography on forest resources and their utilization for this part of the United States.

Previous publications in this series include:

1. The Setting
2. Forest Insects
3. Fish Habitats
4. Wildlife Habitats
5. Soil Mass Movement
6. Forest Diseases
7. Forest Ecology and Timber Management
8. Water

Robert E. Buckman

ROBERT E. BUCKMAN, Director
Pacific Northwest Forest and Range
Experiment Station
Portland, Oregon

CONTENTS

INTRODUCTION

Forests are a dynamic biological phenomenon requiring constant monitoring in order to determine, understand, and update our knowledge of the resources for regional, State, and national management planning. Forest inventory is such a monitoring system. It concentrates, first of all, on estimating the magnitude of the timber resource, and then on describing the stands in terms of conditions and changes due to natural and manmade causes.

Forest inventory work began in southeast Alaska in 1954.[1] One of the first tasks was to determine the land area of the mainland, the various islands, and the working circles used by Region 10 of the U.S. Forest Service in managing forests. This was done using 1:250,000 scale maps.[2] Inventory is done by sampling; a double sampling technique has been followed in southeast Alaska. The first sample consists of classifying a large number of point locations on aerial photos. A sample of these are then randomly selected and field checked for land classification accuracy and measured for tree and volume data.[3]

By 1962, all field and office work had been completed for the initial southeast Alaska inventory and the results included in a report titled "Alaska's Forest Resource" (Hutchison 1967).

INITIAL INVENTORY

The forested area of southeast Alaska is estimated to be 11,201,000 acres,[4] or about 46 percent of the total land area. This area includes all land now at least 10 percent stocked with trees and land that formerly had tree cover and is not being used for any nonforest purpose.[5]

The area defined as commercial forest land has a minimum of 8,000 board feet (International 1/4-inch rule) of sawtimber per acre, or is capable of producing this amount, and a minimum area of 10 acres. The commercial forest area was estimated to be 4,884,000 acres (does not include 194,000 acres that are productive but reserved from harvesting).

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[1] Authorized by the McSweeney-McNary Forest Research Act of May 22, 1928, as amended by the 83d Congress.

[2] H. E. Andersen. April 9, 1954, memorandum on file at Forestry Sciences Laboratory, Juneau, Alaska.

[3] Specific procedures are in "Plan for Forest Survey of Southeast Alaska, April 14, 1954" and in revisions of November 1954, April 1956, and February 1957, on file at Forestry Sciences Laboratory, Juneau, Alaska.

[4] See appendix for metric equivalents of area and volume.

[5] See appendix for more exact definitions of terms.

FOREST OWNERSHIP AND MANAGEMENT UNITS

National Forests encompass 92 percent of the commercial forest land. Because townsites, homesteads, and mining claims account for so little area, they have only very local influence on overall forest management problems and objectives. The State has an important management unit north and west of Haines, and other lands are being selected for State ownership in the vicinity of existing towns. Glacier Bay National Monument contains about 179,000 acres of commercial forest land. This land is withheld from timber harvesting activities in order to thoroughly preserve outstanding scenic values. The ultimate settlement of the Native land claims will affect as much as 400,000 acres of coastal Alaska National Forest land. More forest area than nonforest area will be selected. Likely as much as 200,000 acres or about 4 percent of the commercial forest land of southeast Alaska will change ownership.

For management purposes the forests were divided into units as shown in figure 1, and the forest inventory program conforms to these same boundaries.[6]

FOREST AREA BY STAND TYPES

Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) forest types together account for 89 percent of the commercial forest area. These two species are by far the most important in the State by volume, value, and use. They account for at least 99 percent of the present log production.

Western hemlock is dominant on about 2.7 million acres. On 636,000 acres, Sitka spruce comprises 50 percent or more of the stand volume. On 1 million acres, hemlock and spruce are mixed, with spruce making up 30 to 49 percent of the stand (Hutchison 1967).

Most of the cedar found in Alaska is in the southeast forests. The area in cedar is about equally divided between western redcedar (*Thuja plicata* Donn) and Alaska-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach).

Hardwoods are found mostly along the drainages. Commercial stands of black cottonwood (*Populus trichocarpa* Torr. & Gray) are found in several localized areas. The Stikine, Taku, Haines, and Yakutat areas are the more important.

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[6] Statistical summary tables for the initial forest inventory of the Juneau unit (1957), the Sitka unit (1958), the Petersburg unit (1959), the Yakutat unit (1959), and the Ketchikan unit (1962) have been processed and are available at Forestry Sciences Laboratory, Juneau, Alaska.

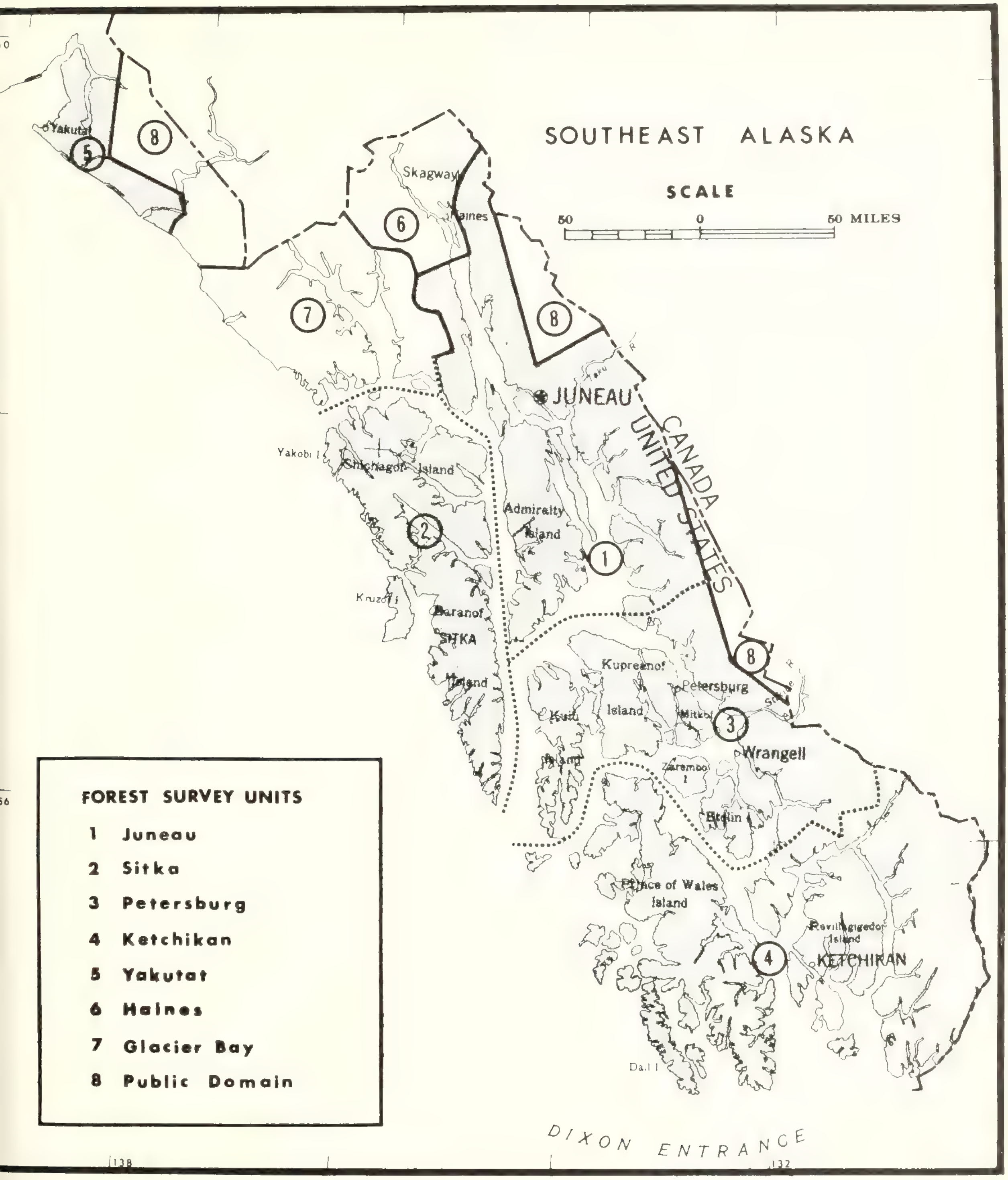

Figure 1.--Southeast Alaska showing Forest Survey units. The shaded areas are management units of the Tongass National Forest.

FOREST AREA BY STAND-SIZE CLASSES

Forest land was separated into commercial and noncommercial classes (table 1). In a further classification of commercial forest land, five stand conditions were recognized: (1) old-growth sawtimber, (2) young-growth sawtimber, (3) poletimber, (4) seedling and sapling, and (5) nonstocked.

Table 1.--Forest areas and timber volume estimates with associated sampling errors, southeast Alaska, 1954-58

Forest Survey unit	Commercial forest		Noncommercial forest		Total volume		Sampling error of total		Sampling error per million ft³
	Area	Sampling error	Area	Sampling error			Fbm	Ft³	
	Thousand acres	Percent	Thousand acres	Percent	Million fbm[1]	Million ft³	- - - - - -	Percent	- - - - - -
Juneau	815.0	2.5	832.0	2.5	26,764	5,194.9	4.9	4.6	2.0
Sitka	540.7	3.3	1,199.5	1.8	19,470	3,704.5	5.5	5.6	2.9
Petersburg	1,029.2	2.3	1,327.4	1.9	36,584	7,021.9	5.1	5.9	2.2
Ketchikan	1,951.0	1.4	2,297.3	1.3	71,155	13,595.8	4.2	3.5	.9
Yakutat	276.6	4.6	38.6	14.8	5,731	1,055.6	10.1	7.9	7.7
Other	271.5	--	428.2	--	6,196	1,222.0	--	--	--
Total	[2]4,884.0	--	6,123.0	--	165,900	31,794.7	--	--	--

[1] International 1/4-inch rule.
[2] Does not include 194,000 acres that are productive but reserved from harvesting.

These classes are important to the forest manager as well as to those interested in timber harvesting. Many old-growth sawtimber stands, for example, are recognized as having reached or passed physiological maturity. Such stands are no longer growing vigorously. Young-growth sawtimber, poletimber, and seedling-sapling stands, on the other hand, are characterized as vigorous, healthy stands which under management could contribute a maximum amount of wood annually through net growth (fig. 2). The overmature, old-growth stands are those the forest manager must harvest first in order to increase the overall productivity of the forest. Many old-growth stands are also wanted by timber buyers and operators because they contain the best quality logs.

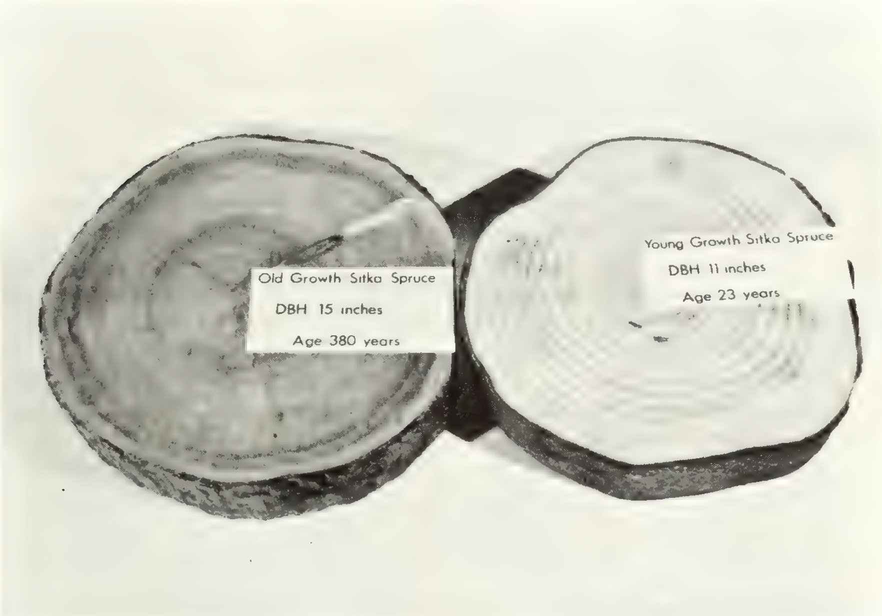

Figure 2.--Cross section on the left came from an uneven-aged, old-growth stand. The section on the right, showing much faster growth, came from an even-aged, young-growth stand.

The commercial forest area of southeast Alaska is 87 percent old-growth sawtimber (fig. 3). Thus, we have 4.2 million acres of forest land which may be considered beyond the optimum age for harvesting. Currently, about 20,000 acres are being cut annually. Because of the unbalanced conditions of the total forest from a timber management viewpoint, the annual volume harvested can exceed the amount being grown for many years before sufficient young stands will be obtained to bring growth and cut into balance. This occurs because there is almost no net growth on areas of old growth, and therefore a static condition exists on 87 percent of the area. Growth will equal harvest, at allowable sustained yield rates, at some time in the future when most of the area is in thrifty young-growth stands.

Figure 3.--Sawtimber stands with trees averaging 150 years or older are classified as old growth. This stand on the southwest side of Tuxekan Island is 160 years old.

For the most part, younger stand sizes occur as scattered, small patches near tidewater. Many of these small tracts were logged earlier because they were easily accessible and possessed high volumes of quality timber. Young stands are also commonly found on areas of windthrow, glacial retreat, land uplift, old burns, and stream channel changes. Many landslides occur on the steep slopes, and these usually restock with forest growth. If these areas have not restocked satisfactorily, they are included in the nonstocked stand-size classification.

GROWING-STOCK VOLUME

The growing-stock volume is estimated at 31.8 billion cubic feet of sound wood in southeast Alaska. By species the volume is distributed as follows:

Species	Percent
Western hemlock	63.9
Sitka spruce	28.1
Western redcedar	3.2
Alaska-cedar	3.7
Cottonwood	.7
All other	.4
	100.0

The distribution of western hemlock and Sitka spruce volume is about the same in the Juneau, Sitka, Petersburg, and Ketchikan units, with western hemlock predominating. In the other units, however, Sitka spruce dominates.

All of the western redcedar is found on the Petersburg and Ketchikan units. The Sitka, Petersburg, and Ketchikan units have most of the Alaska-cedar, although scattered trees and stands are also located on the Juneau unit.

SAWTIMBER VOLUME

The commercial forests contain a total net volume of 166 billion board feet (International 1/4-inch rule) of sawtimber, or 90.5 percent of the growing-stock volume. The importance of this figure depends upon the distribution of volume. Areas supporting high volumes per acre are usually more operable, economically, than those supporting low volumes per acre.

These southeast Alaska forests, with 77 percent of the commercial sawtimber volume in Alaska, average more than 30,000 board feet (net) per acre. The range per acre is from 8,000 to more than 100,000 board feet. These stands are attractive for industrial development, but some competing regions offer as much or more in quantity, quality, and preferred species. The forests of western Oregon and Washington have half the total sawtimber on the Pacific coast; and Douglas-fir, which is the preferred industrial species, comprises most of the volume. However, the average volume per acre of sawtimber stands in southeast Alaska compares favorably with hemlock and spruce stands in Oregon and Washington. This region has nearly 80 percent of the Nation's total supply of Sitka spruce.

Soils and drainage are so complex and variable that the better stands are not always found on the benches and valley bottoms where they might ordinarily be expected. Muskegs (fig. 4), with the inherent characteristic of poor drainage, often occur on locations that otherwise would produce good timber. Most of the good stands of timber are, however, within a few miles of tidewater (fig. 5). According to one estimate (Heintzleman 1949, p. 366) for coastal Alaska, "Three fourths of the commercial forest timber is within 2-1/2 miles of the coast line."

Figure 4.--Muskeg areas, such as this, are common throughout southeast Alaska forests.

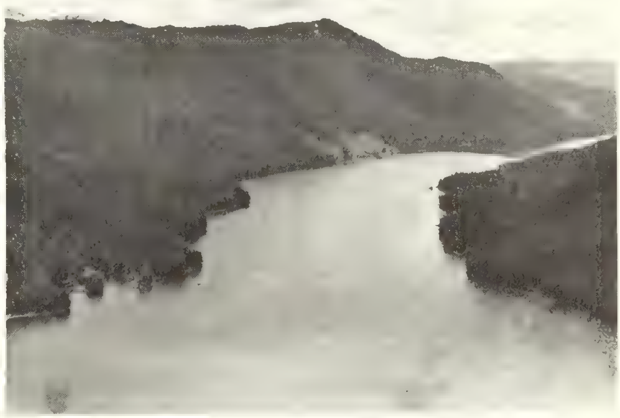

Figure 5.--The Alexander Archipelago in southeast Alaska contains many arms and inlets with timber extending from tidewater to timberline at 2,500 to 3,000 feet.

The Ketchikan unit, with nearly twice as much sawtimber as any other unit, has a greater total land area and a higher proportion of commercial forest land. The character of the commercial forests changes northward and westward from the Ketchikan unit. Volumes per acre tend to decline, trees are generally of poorer quality, and the stands become less extensive.

Hemlock and Sitka spruce together account for 94 percent of the board-foot volume--101 and 54 billion board feet, respectively. Alaska-cedar and western redcedar account for about 4 billion board feet each. Most of the 1 billion board feet of hardwood is black cottonwood. The remaining 2 billion board feet consist of other softwoods, mostly true fir and lodgepole pine (*Pinus contorta* Dougl.). Although western hemlock and mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.) comprise most of the volume, the largest and best quality trees available are Sitka spruce. Sitka spruce is rather evenly distributed, accounting for about one-third of the volume. The proportion increases to 80 percent in the Yakutat unit.

Most of the volume is in the 21- to 30-inch class. More than one-third of the volume is in trees with diameters greater than 30 inches b.h. In general, the spruce is larger than the hemlock. More than 50 percent of the spruce volume is in diameters greater than 30 inches. These trees produce high-quality spruce logs. Such trees are more common on the units south of Yakutat. Although the Yakutat unit has smaller trees, the average net volume per acre is slightly higher than that for the balance of southeast Alaska. This likely is accounted for by a lower incidence of defect at Yakutat associated with younger stands and a higher predominance of spruce.

LOG QUALITY AND TREE DIAMETERS

In the past, coastal stands have often been described as mature or overmature, of declining quality, and suitable primarily for the manufacture of pulp. Much of this is true, but intermixed in these predominantly pulpwood stands is a good supply of the finest quality Sitka spruce and western hemlock to be found anywhere. To attain full utilization, more attention must be given to determining the supply and value of the high-quality logs and to diverting them to their highest use.

For many years, southeast Alaska has produced logs and cants for manufacture of high-quality specialty products. During World War I (USDA Forest Service 1954), and especially during World War II, this region supplied much of the high-quality spruce used in aircraft. In this region, 14 billion board feet of the spruce and hemlock are in Select, Peeler, and No. 1 grade logs. These logs are desirable for the manufacture of veneer, plywood, and high-quality lumber products. The high-quality volume in the stands amounts to about 5 percent of the total hemlock and 16 percent of the spruce sawtimber volume. In the early 1960's most of the harvested volume went for the production of dissolving pulp, worth about $170 a ton in 1972-73. Now most of the high-quality spruce logs are diverted to sawmills to be cut into cants for the Japanese market. Some high-quality hemlock and spruce still go into dissolving pulp, along with all low-quality logs. Whether the yield of pulp is greater from these high-quality logs than from lower quality logs is not known. But it is known that the supply of high-quality logs has diminished in other regions, causing veneer, plywood, and other producers there to use relatively low-grade logs.

Log quality is, of course, closely related to tree diameter. Among the larger trees, more high-quality logs can be expected. Select grade Sitka spruce logs must be at least 30 inches in diameter, measured inside the bark at the small end. Peeler and No. 1 grade hemlock logs must measure at least 24 inches.

More than 58 percent of the Sitka spruce sawtimber volume is in trees with 31-inch or larger d.b.h. Twenty-five percent of the volume in these trees is in either Select or No. 1 grade logs. Thirty-nine percent of the hemlock sawtimber volume is in the 21- to 30-inch diameter class and another 30 percent is in diameters of 31 inches or larger.

If stand quality were evenly distributed throughout the commercial forest land in the region, logging operators could expect to obtain about 2,800 board feet per acre in No. 1 or better grade logs. Since the stands are not uniform in quality, only the better stands are in demand for harvesting. Some of the better stands, now bypassed because the cost of reaching them is too great, occur as small, isolated pockets, behind muskegs, on steep slopes, in side drainages, and in other hard-to-reach places. These stands are likely to remain unharvested until more versatile logging methods and favorable economic conditions appear.

There appears to be an opportunity to develop a much more integrated wood-using industry than now exists. Some of the high-quality logs, particularly Sitka spruce, are now sorted from the pulpwood rafts and sold to sawmills; but very few are processed to a finished product. Most are cut into cants for export to Japan. Per capita use of plywood and veneer in the United States is expected to increase from 87 square feet in 1970 to 125 to 139 square feet in 2000. About 78 percent of this demand is expected to be for softwood plywood and veneer (USDA Forest Service 1974). Some other areas producing softwood plywood and veneer are facing raw material supply problems (Cowlin and Forster 1965). Southeast Alaska has 79 percent of the Sitka spruce and 40 percent of the western hemlock sawtimber in the United States (USDA Forest Service 1974). With so much of the total raw material, this region can supply many industries using these species.

ALLOWABLE HARVEST (PRESCRIBED CUT)

Allowable cut, or yield determination, is defined as "The calculation, more directly by volume regulation, less directly by area regulation, of the amount of forest produce that may be harvested, annually or periodically, from a specified area over a stated period, in accordance with the objects of management" (Society of American Foresters 1971). Each forest manager, whether managing public, industry-owned, or private land, computes the allowable harvest based on given or chosen factors that guide his management objectives such as amount of money to be invested in management, timber merchantability, accessibility, utilization standards, markets, and operating conditions. In southeast Alaska, accessibility (fig. 6) has been an important consideration and limiting factor in allowable harvest determination. Guides used in the past would not necessarily apply today because logging, milling, and road-building values, methods, and policies have changed and will continue to change. An entirely different and legitimate allowable harvest for the same forest can easily be computed by using different definitions for these factors.

GUIDES TO ACCESSIBILITY

Forest Survey
Juneau, Alaska
11/23/55

A. Basic Assumptions
   1. Market exists (on present economic and operability standards).
   2. Minimum net volume yarding tree can support = 500 MBM.
   3. Minimum of 16 M/A average net required immediately behind area that can be directly yarded to protected beach or truck road.
      a. Minimum set volume cold deck tree can support = 750 MBM.
      b. Maximum of one (1) cable swing from cold deck to yarding tree.
         thence (1) Directly to beach
         or (2) Truck to beach
         or (3) Cat swing to beach
      c. Well-spaced cold deck beach 100' x 150', or easily built.

B. Controlling Factors

SHOW	LOGGING METHOD	ROAD BUILDING FACTORS	MAXIMUM REACH[1] Horiz. (Photo) Dist. Level	50%	100%	RATIO Slope Dist./Horiz. 33'/ch. (50%)	66'/ch. (100%)	NOTES[2]
Large Valley	Road, with High Lead	Refer to Table below	Yarding 1000'	900'	700'	1.1	1.4	
			Swinging 1200'	1090'	860'			
Gentle slope, beach front	Cat, or Donkey yard & cat swing	--	1000' 3/4 mi	900' Maximum	700'	1.1	1.4	Cat, 30% (20'/ch.) Max. Oper.
Beach Front	"A" Frame	--	2000'	1800'	1400'	1.1	1.4	
Steep Slope Beach Front	Skidder	--	2600'	2360'	1860'	1.1	1.4	40MMBM per show; protected H_2

[1]Steep gullies, cliffs cause loss of deflection, cable wear, excessive breakage.
[2]Muskeg-nonpaying distance; shallow soil limits road bldg., spar trees, cats.

ROAD BUILDING ACCESSIBILITY FACTORS

Av. vol. per acre MBF	[1]Acres timber required at these road distances (miles) 1/2	1	2	3	4	5	6	7	8	9	10
10	375	750	1500	2250	3000	3750	4500	5250	6000	6750	7500
20	187	375	750	1125	1500	1875	2250	2625	3000	3375	3750
30	125	250	500	751	1001	1251	1501	1751	2002	2252	2502
40	94	187	375	562	749	936	1123	1310	1498	1685	1872
50	75	150	300	450	600	750	900	1050	1200	1350	1500
60	62	125	250	174	499	624	749	874	998	1123	1248

[1]Average cost logging road $30,000/mile; $4/MBF allocated for roadbuilding purposes. Weigh all factors--terrain, available gravel, muskegs, number spur roads, etc.

Multiply x 2/3 for easy road construction, x 5/3 for difficult road construction

360° - Tree Maximum Reach Horiz. (Photo) Dist. feet	Theoretical acreage[1]	Ave. Net. Vol./Acre	Acreage Encompassed 500M[1] per yard. tree	750M per cold deck tree
600	26	16	31	47
800	46	20	25	38
1000	72	30	17	25
1200	104	40	12	19
1600	185	50	10	15
2000	288	60	8	12
2400	415	70	7	11

[1]Reduce accordingly for fractions of tree, arc of reach of floating A-frames.

Figure 6.--During the initial inventory, each photo and field location was classified according to accessibility by the above guides.

A precise allowable harvest cannot be computed for southeast Alaska as a whole since this would require knowledge of management objectives for all areas and ownerships. However, because 92 percent of the commercial forest land is in National Forests, the allowable harvest computed for these forests determines, for practical purposes, the potential commercial development of this region.

The Tongass National Forest contains about 4-1/2 million acres of commercial forest land. The allowable annual harvest is currently placed at 820.3 million board feet (Scribner log scale). However, only 3.2 million acres (65 percent of the commercial forest land) were classified in the initial inventory as accessible. Allowable harvest was computed for this land. As cheaper and more efficient logging methods are developed, as markets improve, as demand for stumpage increases, and as timber becomes scarcer, more and more of the 1-1/2 million acres initially classified as inaccessible commercial forest land will become economically operable and be brought into the allowable harvest computation. It is estimated that this inaccessible commercial forest land could eventually support an annual harvest of about 400 million board feet. An offsetting factor, however, will be demands on management to set aside commercial forest land for other uses, thereby limiting timber harvest. On the other hand, more intensive timber management could ultimately increase yields.

Improved markets for Alaskan timber may increase the allowable harvest in future years. At the time the initial allowable harvest was determined, there was no active market for western redcedar and Alaska-cedar (fig. 7). Therefore 7.8 billion board feet in these two species was not included in the initial allowable harvest computation. Since then some cedar logs have been exported, small amounts have been sawn into lumber for local use, and most recently a shingle mill has begun to operate. As cedar markets improve, these species should be included in the allowable harvest.

Figure 7.--An Alaska-cedar tree, 42 inches in diameter and 87 feet tall, growing on a poor site at Cape Fanshaw.

In computation of allowable harvest the difference between inventory Scribner volume and the scaled log volume as utilized is recognized. Scaled log volume is only about 73.6 percent of inventory volume. The difference between inventory and scaled volume is caused by (1) losses from breakage and other residues during logging, (2) use of the 16-foot-log volume table for inventory when average scaled length is about 32 feet, and (3) scaling diameters rounded to the last full inch, whereas inventory volumes are based on rounding diameters to the nearest inch. The allowance for these factors reduces the inventory volume estimate by about 26.4 percent. As utilization practices improve, more of the inventory volume will end up in products.

In 1973, the timber cut from the Tongass National Forest amounted to 588.5 million board feet (Scribner Bureau scale), about 72 percent of the allowable harvest. If the planned installation of one more large pulpmill, some green veneer production, and some increased sawmill capacity are accomplished, the total present allowable harvest on National Forest lands will be utilized.

REMEASUREMENT OF GROWTH, MORTALITY, AND VOLUME

Since the initial inventory, about 31 percent of the original field plots have been remeasured on the five major southeast Alaska inventory units; and the Yakutat, Juneau, Sitka, and Petersburg units have been completely reinventoried. All of coastal Alaska is scheduled for remeasurement and reinventory.

Data were collected to provide estimates of forest change and trends based on the remeasurement of 269 forest survey field locations over a 7-year period. Of these 269 locations, 215 were systematically selected from the initial forest inventory of southeast Alaska. To improve estimates of growth and mortality trends in young-growth stands, 44 additional locations were measured in young-growth stands of southeast Alaska. Also, 10 additional locations were measured in old-growth stands on the Yakutat unit to improve the reliability of estimates for that unit.

GROWTH

Table 2 summarizes annual gross and net growth and mortality as a percent of total inventory for the period between 1954 and 1968. Net growth and mortality are influenced by catastrophic losses during this period and, therefore, are not always valid as estimates from the long-range viewpoint. Until reliable long-term mortality rates can be determined, gross growth may give a better comparative measure of forest growth.

In initial inventory work, it was assumed that growth of old-growth stands was offset by mortality. In table 2 it can be seen that this was a reasonable assumption.

Unmanaged young-growth stands are producing gross annual cubic-foot growth at a rate 3.36 times that of old-growth stands (table 2). Partly, this is because the annual cubic-foot mortality rate in old-growth stands is three times that of the unmanaged young-growth stands. The gross growth rate is relatively uniform for young-growth stands throughout southeast Alaska. The Ketchikan unit has the highest rate, and the lowest rate is in the Petersburg unit. More knowledge of soils and site distribution and other factors is needed to account

Table 2.--Summary of annual growth rates, southeast Alaska, 1954-68

Unit	Old-growth stands			Young-growth stands			Combined stands		
	Annual net growth	Annual mor-tality	Annual gross growth	Annual net growth	Annual mor-tality	Annual gross growth	Annual net growth	Annual mor-tality	Annual gross growth
	Percent of total study volume								
Juneau:									
Cubic feet	0.28	0.34	0.62	1.56	0.19	1.75	0.36	0.33	0.69
Board feet[1]	.31	.31	.62	1.36	.10	1.46	.37	.30	.67
Sitka:									
Cubic feet	.11	.25	.36	1.35	.20	1.55	.13	.25	.38
Board feet[1]	.06	.25	.31	1.45	.17	1.62	.08	.25	.33
Petersburg:									
Cubic feet	.01	.51	.52	.91	.16	1.07	.03	.51	.54
Board feet[1]	.05	.48	.53	1.01	.08	1.09	.07	.47	.54
Ketchikan:									
Cubic feet	-.16	.63	.47	2.12	.13	2.25	-.13	.63	.50
Board feet[1]	-.10	.61	.51	1.82	.06	1.88	-.08	.60	.52
Southeast Alaska except Yakutat:									
Cubic feet	-.02	.51	.49	1.57	.17	1.74	.02	.50	.52
Board feet[1]	.02	.49	.51	1.41	.09	1.50	.05	.48	.53
Yakutat:									
Cubic feet	.34	.25	.59	1.46	.11	1.57	.66	.21	.87
Board feet[1]	.41	.26	.67	1.49	.07	1.56	.64	.23	.87
Total, all southeast Alaska:									
Cubic feet	0	.50	.50	1.53	.15	1.68	.04	.49	.53
Board feet[1]	.03	.48	.51	1.43	.09	1.52	.07	.47	.54

[1] Scribner rule.

for these differences. The average site index at Yakutat has been estimated at 80 (80 feet at 100 years of age) compared to an average of 103-108 for the balance of southeast Alaska.[7]

MORTALITY

While the remeasurement study provided the first reasonably reliable look at tree mortality rates and the causes (table 3), there is much need for improvement in the estimates. Studies covering different periods might well produce different estimates, largely because of the incidence of catastrophes.

[7] Region 10 Timber Management Plans, USDA Forest Service, Division of Timber Management, Juneau, Alaska.

Table 3.--Summary of annual mortality by cause of death, southeast Alaska, 1954-68

Unit	Insects	Disease	Windthrow	Animal	Other, including landslides	Total
	Percent of total loss					
Juneau:						
Cubic feet	7.0	66.9	20.8	0	5.3	100.0
Board feet[1]	6.8	67.4	21.2	0	4.6	100.0
Sitka:						
Cubic feet	19.6	54.9	25.3	0	.2	100.0
Board feet[1]	21.0	54.3	24.7	0	0	100.0
Petersburg:						
Cubic feet	1.0	39.5	21.5	.3	37.7	100.0
Board feet[1]	.7	38.1	21.2	.2	39.8	100.0
Ketchikan:						
Cubic feet	.4	19.5	29.0	1.1	50.0	100.0
Board feet[1]	.3	19.1	28.7	.9	51.0	100.0
Southeast Alaska except Yakutat:						
Cubic feet	2.5	31.3	26.3	.7	39.2	100.0
Board feet[1]	2.3	30.1	26.2	.6	40.8	100.0
Yakutat:						
Cubic feet	2.1	16.9	71.5	0	9.5	100.0
Board feet[1]	1.0	15.5	79.4	0	4.1	100.0
Total, all southeast Alaska:						
Cubic feet	2.5	31.0	27.1	.7	38.7	100.0
Board feet[1]	2.3	29.8	27.2	.6	40.1	100.0

[1] Scribner rule.

Mortality due to disease in natural forests tends to be greatest in the Juneau unit and decreases in the Sitka, Petersburg, Ketchikan, and Yakutat units.[8] Windthrow mortality (fig. 8) is reasonably consistent across all units in southeast Alaska. Although when shown as a percent of total mortality (table 3), Yakutat appears to have 300 percent more windthrow, it has only 20 percent more on a per-acre basis. Tree mortality due to animal causes is a relatively minor factor in this region.

[8] A cull study in progress at Forestry Sciences Laboratory, Juneau, Alaska, shows this same pattern of losses due to disease.

Figure 8.--One storm in November 1968 blew down millions of board feet in stands as shown here. Also note the landslide in the center of the picture.

In the category, "Other mortality," one of the greatest contributing causes is natural landslides (fig. 9) in forest stands (Swanston 1969). This was especially evident in the Ketchikan Working Circle, where mortality due to a landslide was by far the predominating factor.

VOLUME

The remeasurement gave a highly significant difference in volume estimates for the Juneau and Yakutat units but no significant difference for the other units or for all units combined (table 4).

Figure 9.--Many landslides similar to the one pictured here at Walker Cove occur throughout southeast Alaska.

Table 4.--Comparison between initial and remeasurement average cubic-foot volumes, southeast Alaska

Unit	Number of locations used in analysis	Initial inventory	Remeasurement	Difference
		Mean net cubic feet acre		
Juneau	35	5,782	6,176	394**
Sitka	23	7,247	7,071	176ns
Petersburg	36	5,947	5,908	39ns
Ketchikan	59	7,716	7,638	78ns
Southeast Alaska except Yakutat	153	6,787	6,811	24ns
Yakutat	45	6,449	5,862	587**
Total, all southeast Alaska	198	6,711	6,596	115ns

NOTE.--** = Significant at 1-percent probability level.
ns = Nonsignificant at 5-percent probability level.

REINVENTORY

THE YAKUTAT UNIT

The Yakutat unit was initially inventoried in 1957 and totally remeasured in 1967. The volume and area estimates resulting from the 1967 remeasurement are summarized in Forest Survey Report No. 7, "Forest Inventory Statistics for the Yakutat Area of Alaska, 1967,"[9] compiled by Robert B. Mattson. Basically, the initial inventory sampling designs and standards were followed. The highlights of the two studies are summarized in table 5.

Table 5.--Comparative summary of two Yakutat forest inventory estimates

Item	1957 inventory	1967 remeasurement
1. Total photo points	872	2,310
2. Total ground locations on commercial forest land	57	77
3. Total area (acres)	795,900	767,000
4. Estimated area of commercial forest land (acres)	276,600	208,000
5. Sampling error for item 4 (percent)	±4.6	±3.8
6. Estimated area of operable commercial forest land (acres)	[1]230,750	[2]110,100
7. Estimated total net volume (Scribner M bm)	5,231,751	5,600,000
8. Sampling error for item 7 (percent)	±10.1	±8.9
9. Estimated total operable net volume (Scribner M bm)	5,103,672	4,611,000
10. Average net volume per acre all commercial forest (Scribner M bm)	18.2	26.9
11. Average operable net volume per acre commercial forest (Scribner M bm)	22.1	41.9

[1] Includes 88,300 acres in stands less than sawtimber size.
[2] Includes only sawtimber stands. Operability criteria used for the remeasurement were more restrictive than those used for initial inventory work (fig. 6).

[9] Report on file with U.S. Forest Service, Regional Forester's office, Division of Timber Management, Juneau, Alaska.

Some of the differences in estimates between the two inventories can be attributed to a change of area boundaries in 1967. Some differences are attributed to more reliable measurements in 1967 and to growth during the 10-year interval. Estimates of area and volume that are operable or accessible according to the two surveys are not strictly comparable. Operability criteria used for the remeasurement were more restrictive than those used for the initial inventory work. Because economic conditions and harvesting methods change, operability criteria that might be used today would not necessarily agree with criteria used in the past surveys.

THE JUNEAU AND SITKA UNITS

A complete reinventory program was started in 1970 to reevaluate the southeast Alaska forest area and volume. Several new categories of information were collected, including data to evaluate level of stocking, volume strata classes, soil classifications, multiple use classifications, degree of slope, revised operability guides, and revised quality guides. Further, more detailed data were collected on the individual trees to better determine the management potential, such as risk class and soil microsite. In all, 185 variables are on file for each tree tallied. Table 6 gives preliminary comparison of basic information.

The Juneau and Sitka units show an increase in commercial forest volume of about 30 percent and 20 percent, respectively, when compared with the original inventory estimates (table 6). The increase is largely the result of an increase in the commercial forest land base of the units.

Table 6.--Comparison of two inventories, Juneau and Sitka units

Item	Juneau unit		Sitka unit	
	1954	1970[1]	1957	1971[1]
Sampling:				
Photo locations (number)	5,830	14,404	3,314	11,771
Field locations (number)	485	475	328	567
Field locations on commercial forest land (number)	164	192	129	180
Area:				
Total (acres)	3,832,800	4,090,200	2,433,300	2,571,800
Commercial forest land (acres)	817,500	1,321,635	540,700	821,675
Sampling error, commercial forest land (percent)	2.5	2.2	3.3	2.4
Volume:				
Commercial forest land (M bm net Scribner)	[2] 23,383,000	[3] 33,539,919	[4] 17,828,984	[3] 20,915,321
Sampling error (percent)	4.9	3.2	5.5	3.6
Average per acre (M bm net Scribner)	28.6	25.4	33.0	25.3

[1] Preliminary data.
[2] Reduced by 8.2 percent to allow for breakage in harvesting.
[3] Not reduced to allow for breakage in harvesting but reduced for volume cut between inventories.
[4] Reduced by 1.8 percent to allow for breakage in harvesting.

In the reinventory, the minimum area criterion for commercial forest land was reduced to 1 acre, whereas the original inventory minimum area was 10 acres. It was expected that this change would result in an increase in the commercial forest area estimate. However, an analysis of all 16,500 commercial forest photo points in the Juneau, Sitka, and Petersburg[10] reinventory units showed that the change in criteria caused only a minimal increase in commercial forest land area. Slightly more than 1 percent of the commercial forest area was in tracts less than 10 acres in size (table 7).

Table 7.--A summary of commercial forest point occurrence by size of forest

Unit	Commercial forest ≥10 acres	Commercial forest <10 acres	Percent of total <10 acres
	Number of photo points		
Juneau	6,432	32	0.5
Sitka	3,701	118	3.1
Petersburg	6,170	46	.7
Total	16,303	196	1.2

Reinventory results indicate that the Juneau and Sitka units have about 217,000 and 95,000 acres with 5.5 and 2.1 billion board feet, respectively, on slopes over 37° (75 percent). Preliminary results for the Petersburg unit show about 143,000 acres with 3.7 billion board feet on these slopes (table 8). The risk of landslides is high where the range of slope angle is 34° to 37° or more (Swanston 1969).

Approximately 47,000 and 27,000 acres in the Juneau and Sitka units, respectively, have stands averaging over 50,000 net board feet Scribner per acre.

In the reinventory, we made the first general attempt to measure area and volume by soil classification units (table 9). All survey units yielded about the same average volumes per acre by soil class. The soil classes had been assigned site indices in previous studies, and this now provides a tool for obtaining a realistic evaluation of site and productivity in old-growth sawtimber stands where height-age relationships are not meaningful. There appears to be an important relationship between soil class site index and average volume of the site. Further study is needed to evaluate how significant this relationship is.

The F3 soil class indicates either ash soil, coarse gravelly outwash soils, or a cobblestone uplifted beach soil. The Juneau study showed no F3 soils in sawtimber stands. The Sitka unit has about 94,000 acres and 2.7 billion board feet, primarily on ash soil.

The F3 ash soil class was of particular interest because the type is known to be unstable on slopes over 35 percent or if exposed on gentler slopes, and this study gave the first estimate of the extent of F3 ash soils. It should be noted, however, that although the bulk of the ash soils will fall in the F3 class, there are also small amounts of ash soil in the F1 and F4 classes.

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[10] Not fully reported in this section because the inventory was only partially compiled as of the time of this report.

Table 8.--Preliminary estimates of area and volume of sawtimber stands by slope percent for the Juneau, Sitka, and Petersburg survey units, Alaska, 1973

Unit and slope (percent)	Area	Volume	Volume per acre
	Thousand acres	Million f bm (Scribner)	M bm (Scribner)
Juneau:[1]			
0-5	117	2,719	23.2
5-15	129	2,757	21.4
15-25	183	4,463	24.4
25-35	142	3,962	27.9
35-45	174	4,179	24.0
45-55	135	3,981	29.5
55-65	156	4,379	28.1
65-75	41	766	18.7
75-85	68	1,677	24.7
85+	149	3,839	25.8
Total or average	1,294	32,722	25.3
Sitka:			
0-5	143	4,079	28.5
5-15	93	2,131	22.9
15-25	90	2,317	25.7
25-35	85	2,269	26.7
35-45	103	2,962	28.7
45-55	68	1,799	26.4
55-65	68	1,760	25.9
65-75	36	921	25.6
75-85	41	949	23.1
85+	54	1,162	21.5
Total or average	781	20,349	26.0
Petersburg:			
0-5	217	5,277	24.3
5-15	156	3,551	22.8
15-25	129	2,703	21.0
25-35	169	4,281	25.3
35-45	169	3,997	23.6
45-55	122	2,709	22.2
55-65	74	2,160	29.2
65-75	47	1,153	24.5
75-85	102	2,884	28.3
85+	41	812	19.8
Total or average	1,226	29,527	24.1

[1] National Forest ownership only.

NOTE.--13.8 percent of the combined unit areas of commercial forest land (455,000 acres) and 13.7 percent of the combined Scribner volumes (11.3 billion f bm) are on slopes over 75 percent and therefore over 37°.

From the site index information by soil class, estimates of average site indices for the Juneau, Sitka, and Petersburg units were determined with a reasonable degree of confidence. Table 9 presents these averages, which increase slightly in magnitude from north to south. This is to be expected.

Table 9.--Preliminary estimates of area and volume of sawtimber stands by soil class for the Juneau, Sitka, and Petersburg survey units, Alaska, 1973

Unit and soil class	Tree site index	Area	Volume	Volume per acre
		Thousand acres	Million f bm (Scribner)	M bm (Scribner)
Juneau:[1]				
F5	70	136	1,975	14.5
F2R	80	291	6,474	22.2
F2,4,6	100	596	15,907	26.7
F3	110	8	1	.7
F1	130	263	8,365	31.8
Total or average	98.8	1,294	32,722	25.3
Sitka:				
F5	70	63	989	15.7
F2R	80	59	1,155	19.6
F2,4,6	100	360	8,665	24.1
F3	110	94	2,717	28.9
F1	130	205	6,823	33.3
Total or average	104.3	781	20,349	26.0
Petersburg:				
F5	70	88	1,374	15.6
F2R	80	102	2,398	23.5
F2,4,6	100	677	14,089	20.8
F3	110	34	643	18.9
F1	130	325	10,985	33.8
Total or average	104.5	1,226	29,489	24.1

[1] National Forest ownership only.

INVENTORY PROJECTIONS--ONE EXAMPLE

With TRAS (Timber Resource Analysis System) as a tool and the remeasurement data as input, it was possible to make several projections to estimate what might happen if certain cutting rates and management alternatives were followed. The background, assumptions, and highlights of one projection are given here as an example of one trend analysis. Many other combinations of assumptions are possible.

In 1971, a nationwide evaluation was made whereby current stands were projected to the year 2020, using three different sets of basic assumptions. As a part of this study, coastal forests[11] were projected 50 years into the future using current management techniques and assuming no change in stumpage prices.

[11] The term coastal Alaska forests includes the Chugach National Forest. Discussion has been confined to southeast Alaska forests, primarily the Tongass National Forest region, as much as possible.

It was necessary to make this projection for coastal Alaska in three parts: one projection for coastal Alaska old-growth stands, one for coastal Alaska young-growth stands, and one for Yakutat stands. In addition, it was necessary to project cutover stands by a bookkeeping system and finally to merge these four projections. International 1/4-inch board-foot volume was used; and it was assumed that the annual allowable harvest (1,244.5 million board feet, International 1/4-inch scale) would come only from old-growth stands, would be obtained in the year 1975, and would hold at that level through the remainder of the projection. It was assumed that 2,000,000 acres of land, including 400,000 acres of commercial forest land, would be withdrawn from forest production between 1970 and 1980 for other uses. No allowance was made for Native Land Claim withdrawals.

Given the above assumptions, basal area per acre dropped from 193 square feet per acre in 1970 to 189 square feet per acre in about 1990 and climbed back to 198 square feet per acre by 2020. Total International 1/4-inch board-foot volume begins at 185 billion board feet in 1957 and drops to 130 billion board feet in 2020.

In approximately year 2025, net board-foot growth will overtake and surpass the annual cut (fig. 10). This projection indicates that inventory will never drop below 125 billion board feet (International 1/4-inch scale). This means that, based on the above projection and assumptions, at no point in the sustained yield plan will the timber supply drop below 67-1/2 percent of the original inventory volume. Net annual growth will overtake annual cut before the original stand drops below that level.

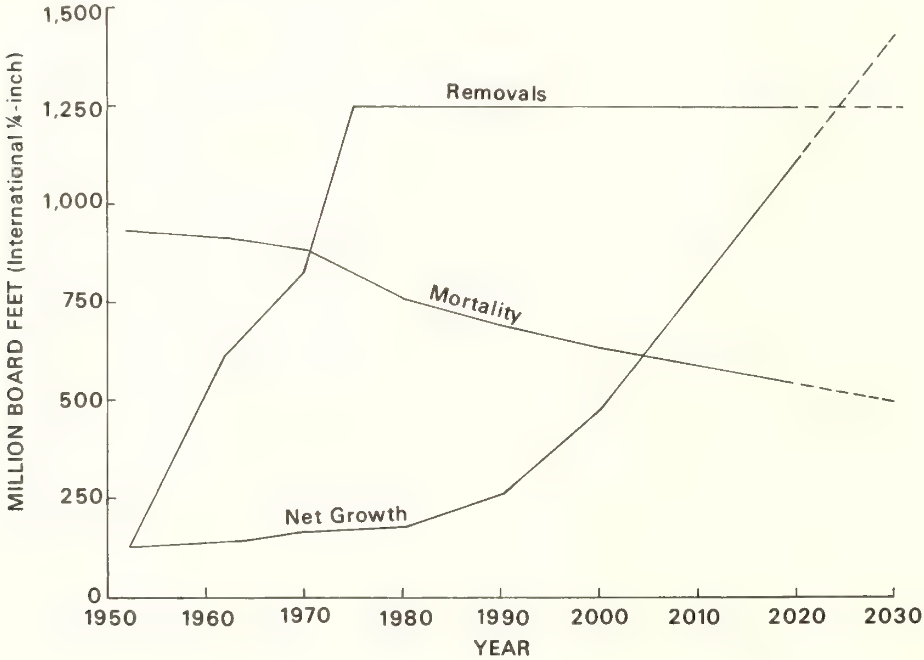

Figure 10.--Projection of removals, net growth, and mortality for coastal Alaska commercial forest land to 2020. Assumes present allowable harvest and no change in stumpage prices.

HARVESTING

CUT

Timber harvesting and processing ranks third, after oil and fisheries, as the most important industry in Alaska (table 10), but ranks first in southeast Alaska (table 11). Southeast Alaska with eight large sawmills and two pulpmills clearly dominates the State's wood processing industry (Clapp 1972). The annual harvest of Alaska timber has always come predominantly from the National Forests of the southeast coastal region. This, of course, is because the high volume per acre stands of western hemlock and Sitka spruce are in the southeast and because 92 percent of the commercial forest land of the region is in National Forests.

Table 10.--Total value of major resource production, Alaska, 1960 and 1967-72

Industry	1960	1967	1968	1969	1970	1971	1972
	- - - - - - Thousand dollars wholesale values - - - - - -						
Fisheries	96,689	126,696	191,686	144,200	213,932	198,660	202,951
Oil and gas	1,260	95,455	191,083	227,129	279,132	286,507	267,270
Minerals	20,600	41,692	30,617	30,514	59,139	46,341	49,890
Forest products	47,300	77,700	89,300	100,900	112,700	118,100	109,800
Total	165,849	341,543	502,686	502,743	664,903	649,608	629,911

Sources: Alaska Department of Economic Development (1972, 1974) and Alaska Department of Fish and Game (1972).

Estimates of the amount of timber cut annually from the National Forests and other forests of southeast Alaska have been difficult to obtain and are subject to reporting and accounting errors. Timber cut from private land, for example, is not reported. Since private lands comprise such a small percent of the total southeast Alaska forest land (less than 1 percent), any error involved in the estimate of timber cut from this sector is insignificant. The public agencies vary in methods of accounting for the amount of timber cut. Some timber is sold on the basis of the estimated amount of standing timber available on a given area, and no measure is made of the amount actually removed. The U.S. Forest Service scales the volume of logs removed, but the relationship of that volume to the estimated inventory volume prior to harvesting is not always known. In 1961-62, a study of 21 logging operations in southeast Alaska showed that 60 of every 1,000 board feet of inventory was left in the woods as residue. [12]

[12] James T. Bones. Relating products output to inventory estimates on the Tongass Forest. Unpublished report on file at Forestry Sciences Laboratory, Juneau, 38 p., illus., undated.

Table 11.--Total value of major resource production and processing, southeast Alaska

Industry	1950	1955	1960	1965	1970	1971	1972	1973
	- - - - - - - - Million dollars wholesale values - - - - - - - -							
Fisheries catch	[1]17.1	[1]11.8	[1]10.2	[1]20.1	[1]20.4	[2]18.0	[2]28.6	[2]42.0
Fish products	[1]38.2	[1]25.8	[1]19.5	[1]39.0	[2]43.1	[2]38.2	[2]60.1	[2]75.8
Stumpage[3]	.1	.5	.9	.8	4.4	4.9	3.6	4.1
Wood products[3]	6.7	27.0	46.2	53.9	93.7	103.5	99.1	122.0
Minerals[4]	.2	.2	.9	4.2	5.5	--	5.4	--

Sources: [1] U.S. Bureau of Commercial Fisheries (1953-73).
[2] Alaska Department of Fish and Game (1970-73).
[3] U.S. Forest Service, Region 10. Unpublished preliminary estimates for National Forest production only. Available at Juneau.
[4] U.S. Bureau of Mines (1953-74).

Table 12.--Sawtimber volume and acres removed from inventory by cutting, coastal Alaska, 1950-73

Year	National Forests	All other	Total	Percent from National Forests	Estimated acres cut from National Forests
	M bm (International 1/4-inch scale)				
1950	83,736	17,371	101,107	82.8	--
1951	81,970	16,483	98,453	83.3	--
1952	92,890	29,025	121,915	76.2	--
1953	89,182	27,845	117,027	76.2	--
1954	155,028	14,646	169,674	91.4	--
1955	305,507	17,224	322,731	94.7	--
1956	324,294	34,607	358,901	90.4	5,783
1957	321,657	47,158	368,815	87.2	6,772
1958	245,426	11,172	256,598	95.6	5,217
1959	382,919	12,988	395,907	96.7	5,789
1960	490,340	14,950	505,290	97.0	8,962
1961	482,265	17,342	499,607	96.5	9,921
1962	521,521	20,110	541,631	96.3	9,649
1963	558,759	22,194	580,953	96.2	11,300
1964	623,225	31,902	655,127	95.1	12,330
1965	566,708	38,911	605,619	93.6	11,040
1966	665,400	48,508	713,908	93.2	11,658
1967	665,902	82,297	748,199	89.0	11,931
1968	744,758	94,406	839,164	88.8	13,589
1969	730,846	95,248	826,094	88.5	13,666
1970	783,402	102,098	885,500	88.5	12,413
1971	739,342	106,785	846,127	87.4	15,460
1972	768,802	120,933	889,735	86.4	13,000
1973	825,874	--	--	--	--

Table 12 shows the annual removal of timber (International 1/4-inch scale) from the inventory since 1950 for coastal Alaska. More than 99 percent of the total coastal Alaska harvest comes from southeast Alaska. The log volume utilized is usually reported in Scribner Bureau scale which is familiar to the industry and logging operators. The volume of logs reaching the mill in Scribner Bureau scale is about 73.6 percent of the timber inventory (Scribner rule). Harvesting of logs for lumber, piling, fish traps, and other local uses has been going on since earliest settlement; but quantities harvested annually have been small. Also the source of logs has been from the best stands and those easily logged from a protected beach (fig. 11).

Figure 11.--A-frame skidders, such as this one operating in Traitors Cove in 1957, are used to log direct to a protected beach. Such operations are less common today, accounting for about 2 percent of the total log production.

Figure 12.--Today the better grades of logs are cut into export squares, as shown here at a southeast Alaska mill.

The Forest Service and other public land managers have required that logs produced from Alaska public forests be processed through the primary stage in Alaska. Lumber produced in Alaska has not been able to compete in price on other than local markets. However, sawn cants have found a ready outlet on the Japanese market in recent years (fig. 12). The market for pulp provided the needed breakthrough, and early in the 1950's a pulpmill began operating at Ketchikan. The sizable increase in timber cut from National Forests in 1954 and 1955 reflects this new market. Another large increase in timber cut took place in 1960. This reflects the beginning operation of a pulpmill at Sitka. Southeast Alaska now has the two pulpmills and eight major sawmills. These eight sawmills each produce from 3 to over 100 million board feet annually, mostly in cants for a Japanese market.

For coastal Alaska, the Forest Service has set an allowable annual harvest of 1.2 billion board feet (International 1/4-inch scale) that can be drawn from the accessible commercial forest land. The sale of timber to supply a third

pulpmill and sawmill complex about meets the allowable harvest. The sale, however, has been challenged by a lawsuit, with the outcome still in question as this goes to press.

Most of the lumber and cants produced in southeast Alaska are exported. Table 13 shows that in recent years 79 to 94 percent of the total Alaska lumber production is exported and of that, 99 percent goes to Japan. In 1973 nine southeast Alaska sawmills produced 440 million board feet of lumber and cants (Forest Industries 1974). Seven of these mills accounted for most of the export.

During a recent 5-year period, pulp production from southeast Alaska timber averaged 386,000 tons annually (table 14). All of the pulp is exported from Alaska, but as much as 40 to 45 percent goes to domestic "lower 48" markets.

With only a few exceptions, round log exports must come from private land. For lack of any other market, the Forest Service allows the export of cedar logs from the National Forest that otherwise would be surplus in logging for spruce and hemlock (fig. 13). In the past 5 years, log exports have totaled 266.6 million board feet--averaging 53.3 million board feet annually (table 13). About 95 percent of the log exports are to Japan.

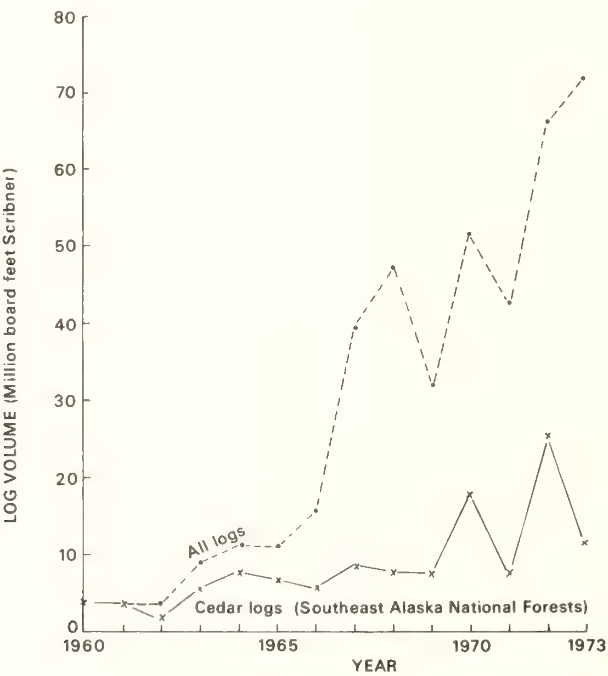

Figure 13.--Log exports from Alaska and export of cedar logs from southeast Alaska's National Forests, 1960-73.

Wood products exports are an important part of Alaska's economy. Without including the value of pulp shipped to the "lower 48," the value of wood products exported to foreign countries exceeds the value of Alaska imports (table 15).

Table 13.--Softwood log and lumber (cants) exports from Alaska,[1] total lumber and cant production for southeast Alaska, and total Alaska lumber and cant production, 1967-73

Year	Alaska exports to Japan				Total Alaska exports		Total southeast Alaska lumber and cant production[2]	Total Alaska lumber and cant production[2]	Percent of total Alaska lumber production exported
	Logs	Percent of total shipped	Lumber (cants)	Percent of total shipped	Logs	Lumber (cants)			
	M bm		M bm		- - - - -	- - - - -	M bm	- - - - -	
1967	37,404	94.7	203,860	99.9	39,512	203,905	226,000	228,000	89
1968	46,371	98.4	243,599	99.1	47,098	245,633	257,000	262,000	94
1969	30,889	96.8	285,432	99.8	31,889	285,894	286,000	336,000	85
1970	47,583	92.3	315,386	99.9	51,531	315,586	305,000	349,000	90
1971	38,948	91.4	245,974	99.4	42,600	247,414	274,000	302,000	82
1972	61,882	94.0	336,798	99.0	65,837	340,196	359,000	411,000	87
1973	71,705	100.0	403,938	99.8	71,719	404,849	440,000	510,000	79
[3]1974	29,088	83.2	361,691	99.8	34,949	362,412	--	--	--

Sources: [1] Holt (1974).
[2] Forest Industries (1968-74).
[3] U.S. Forest Service, Report on softwood log and lumber exports from the Pacific coast (February 18, 1975).

Table 14.--Log, lumber, and pulp production, 1960-73

Year	Coastal Alaska: Log production from National Forests[1]	Coastal Alaska: Total log production	Coastal Alaska: Lumber and cant production	Southeast Alaska: Logs converted to pulp	Southeast Alaska: Pulp production
	Million f bm (Scribner)	Million f bm (Scribner)	Million f bm	Million f bm (Scribner)	Tons
1960	351.1	361.8	--	--	--
1961	345.3	357.7	[2]70	--	[2]266,500
1962	373.4	387.8	--	--	--
1963	399.0	414.9	--	--	369,175
1964	432.8	468.0	--	289	385,431
1965	404.5	432.4	--	293	378,783
1966	475.5	510.2	[3]158	379	401,640
1967	476.8	535.7	228	384	394,953
1968	533.3	600.9	262	379	393,600
1969	523.3	591.5	334	[4]354	394,200
1970	561.0	634.1	346	[4]306	350,500
1971	529.4	605.9	300	[4]300	403,290
1972	550.5	631.3	407	[4]372	394,500
1973	591.6	708.9	505	[4]396	453,825

[1] The Tongass and Chugach National Forests.
[2] Bones (1963).
[3] Massie (1967).
[4] Includes chips from sawmill residues.

Table 15.--Value of Alaska imports and exports, value of wood products from Alaska National Forests, and value of wood products shipped to Japan, 1958-73

Year	Alaska: All imports	Alaska: All exports[1]	End product value of wood products from Alaska National Forests: Total	End product value of wood products from Alaska National Forests: Pulp	Value of southeast Alaska exports to Japan: Pulp	Value of southeast Alaska exports to Japan: Lumber	Value of southeast Alaska exports to Japan: Logs
	Million dollars						
1958	2.0	6.3	24.6	--	--	--	--
1959	3.1	6.5	34.1	--	--	--	--
1960	5.7	19.5	46.2	--	--	--	--
1961	6.4	25.2	45.9	--	--	--	--
1962	8.1	24.4	49.7	--	--	--	--
1963	8.1	32.1	51.4	--	--	--	--
1964	6.9	36.0	57.9	--	22.7	5.0	.3
1965	7.9	36.7	53.9	--	21.0	5.1	.6
1966	10.1	43.3	70.6	61.3	24.4	9.0	.9
1967	11.7	47.4	76.0	67.5	22.7	12.6	2.8
1968	23.7	55.3	89.2	68.9	19.3	17.4	3.3
1969	52.5	92.8	100.6	71.0	22.2	24.6	3.8
1970	78.4	129.9	93.7	64.8	22.8	30.0	6.5
1971	41.3	126.1	103.5	74.6	23.3	25.2	5.0
1972	49.0	180.7	99.1	63.8	26.6	37.8	8.1
1973	39.9	170.2	122.0	62.7	21.2	--	--

[1] Does not include the value of products shipped to "lower 48" markets.
Sources: U.S. Bureau of the Census (1964-73).
Alaska Department of Economic Development (1969, 1971, 1972).

OPERABILITY

For management purposes, the commercial forest land is classified as operable (or accessible) and inoperable (or inaccessible). The inoperable class included stands on unstable soils, slopes too steep to log without doing serious damage to the site, and stands that would not pay the cost of logging, using costs and methods current at the time of inventory. Stands that would require new methods, such as helicopter or balloon logging, were not in the operable class.

In the initial southeast Alaska inventory, 3.2 million acres were classified as accessible commercial forest land and 1.7 million acres were inaccessible. The estimate of annual allowable harvest for the Tongass National Forest is based on the accessible area and sawtimber volume after making deductions for land that is being withheld or is expected to be withheld from timber harvesting. Timber sales are laid out in the accessible stands using the same general guidelines as were used for inventory. Sales of a few million board feet to meet current short-term demand are easily inspected by the buyer and seller to determine operability and value. Long-term sales of several billion board feet to justify construction of plants such as a pulpmill leave agreement on operability to the future. The result has been some controversy over long-term sales between Forest Service foresters and company logging operators regarding the actual amount of land and timber volume that is economically available. To help resolve questions, some units have been reinventoried more intensively. Although some shifting of land between the two classes resulted, the total operable (accessible) areas and volumes remained about the same.

A current National Forest management objective is to map all forest land by multiple use classes and to review economic operability criteria. To help plan the timber harvest, the multiple use classes are being zoned to show standard, special, and marginal harvesting opportunities. For the most part the standard and special zones will include the areas previously classified as operable while the marginal zone will include much that is inoperable.

QUALITY

Log grades are used in timber inventory to determine stand quality and in cruising for timber appraisal purposes. Currently the quality of standing Sitka spruce and western hemlock is estimated by using both U.S. Forest Service and Puget Sound Log Scaling and Grading Bureau specifications applied to 16-foot segments of the standing tree.

Based on the remeasurement inventory, 18.4 percent of the Sitka spruce and 7.9 percent of the western hemlock sawtimber volume is in Grade 1 and better logs (modified application of the Puget Sound Log Scaling and Grading Bureau grading rules). The proportion of the various grades of logs in the timber cut is not known. Logs sent to the pulpmills have not been graded. However, for one 5-year period, 1964-68, a study (U.S. Forest Service, Region 10) was made of six operators who sorted logs for sawmills. According to this study, the Sitka spruce logs sorted for the sawmill by Puget Sound Log Scaling and Grading Bureau grades averaged 27 percent Grade 1 and better by volume, and hemlock logs sorted for the sawmill averaged 30 percent Grade 1 and better. If we assume that the volume used for pulp contains no Grade 1 or better logs, that is that they have all been sorted for sawmill use, then the quality distribution of the total log production would approximate that found in the inventory.

In 1965, 1967, and 1969, three mill recovery studies were made (two on Sitka spruce and one on western hemlock) to provide updated recovery information on export cants and timber quality data for research on new grades. The study in 1965 was at Wrangell Lumber Company on Sitka spruce. Some sample logs were lost at sea during the tow to the mill, and it was determined that additional samples were needed to complete the study. In 1967, additional trees were selected, logged, and sawed (Lane et al. 1972). The 1969 study was on western hemlock.

The lumber or cants produced for export to Japan are usually graded under at least one of two systems. The most common one is a buyer-seller agreed-upon system using grades designated as Piano, A, B, or C. The other is the Standard R List and graded by the Pacific Lumber Inspection Bureau. The yield of each current log grade in terms of these lumber and cant grades was determined for Sitka spruce in the 1965 and 1967 Wrangell studies (Lane et al. 1972).

Based on 400 trees, the report shows that 98 percent of the lumber volume was produced as cants 3 to 8 inches thick. Tables in the report detail the cant sizes by log grade and lumber grade. A comparison is made of the two lumber grade systems. For example, Piano grade cants are about 77 percent No. 2 and No. 3 Clear grade under rules as applied by the Pacific Lumber Inspection Bureau.

In 1969 a study similar to the Wrangell Sitka spruce study was undertaken on western hemlock.[13] The log grade distribution, log scale, and lumber recovery are summarized in table 16.

Table 16.--Summary of western hemlock logs sawn for export cants

Log grade	Number of logs	Gross scale	Net scale	Defect	Recovery ratio	Lumber tally
		- - - Board feet - - -		Percent		Board feet
Peeler	3	2,620	2,310	12	1.25	2,878
No. 1	54	48,370	35,260	27	1.26	44,430
No. 2	567	206,270	163,990	20	1.17	192,017
No. 3	541	62,210	55,210	11	1.27	69,862

Recovery in Grade No. 2 and No. 3 Clear cants was 16 percent for hemlock and 13 percent for Sitka spruce.

The percentage of the cubic volume of commercial logs converted to lumber was 48 percent for hemlock and 56 percent for Sitka spruce. In other words, 52 and 44 percent, respectively, of the total log volume became slabs, edgings, and sawdust. Most of the slabs and edgings are now being made into chips for the pulpmills.

[13] Richard O. Woodfin, Jr., and Thomas A. Snellgrove. Lumber yield from western hemlock in southeastern Alaska. Being prepared as a USDA Forest Service Research Note.

The need for an improved grading system for Sitka spruce and western hemlock has been recognized for some time. Based on the mill recovery data, a new grading system for Sitka spruce timber has been developed for determining timber quality by measurement of specific tree characteristics that reflect total value and total lumber tally volume. The coastal Alaska Forest Survey now is recording these quality characteristics for sample trees on inventory plots.

A comparable grading system is being developed for western hemlock.

TIMBER APPRAISAL

The southeast Alaska timber market differs from "lower 48" markets in several ways:

1. There is a limited product market--primarily for pulp and cants.

2. "Arms length" transactions in logs and lumber are the exception rather than the rule. (An "arms length" transaction is a commercial transaction within a free market and results in a fair market value.)

3. U.S. Forest Service controls 92 percent or more of the available commercial timber.

4. The two pulp producers exercise predominant control over log purchases, logging operations, and the financing of the logging industry.

Region 10 of the U.S. Forest Service is currently developing a procedure for appraising from the end product values of pulp and lumber manufactured in Alaska.

Before the construction and operation of the first pulpmill in Alaska, the principal products produced from Alaska timber were piling, poles, and dimension lumber used for homes, warehouses, docks, fish boxes, and related items. Timber appraisals of National Forest timber before 1958 were based on values and costs collected from local sawmills and loggers. There was no system to recognize stand quality, terrain, difficulty of logging, or other variables ordinarily recognized in timber appraisals.

In 1959 a mill scale study of Sitka spruce lumber was conducted at Ketchikan Spruce Mills. At the time of the study, Ketchikan Spruce Mills was sawing dimension lumber and boards for the Alaska retail market, with a small volume of selected lumber being shipped south to the Puget Sound area. In 1960, the Forest Service began a formal program of cost and value collection in Alaska. Also, a system of recognizing tree quality was devised.[14] This system was applied to the recovery data from Ketchikan Spruce Mills to serve as the basis for selling values of both spruce and hemlock timber. Until 1965, appraisals were made on the value of logs derived from lumber selling values.

The export of cants cut from Sitka spruce to the Japanese market began in late 1950's. The Wrangell Lumber Company at Wrangell, Alaska, pioneered this market.

[14] Leslie J. Sullivan and John F. Shields. Lumber grade recovery from old-growth Sitka spruce on the South Tongass National Forest. Unpublished report on file at U.S. Forest Service, Region 10, Juneau, 8 p., illus., about 1960.

By 1965 the demand for spruce cants in Japan had advanced to the point that the Wrangell Lumber Company output could not meet it. Ketchikan Spruce Mills then began sawing spruce cants along with its usual dimension lumber output.

When the lumber market changed from domestic dimension to foreign cant market in 1968, the base for Forest Service timber appraisals changed with it. Average cant values by species were collected along with average milling costs and overruns. From these data, an average value by net log scale and species was calculated. This average value by log scale and species was distributed to log grade values based on the spread of values traditional to the domestic dimension market which existed in 1966.

Later, as data from the spruce and hemlock cant, mill-scale studies became available, the spread of log values indicated by those studies was substituted for the traditional spread from the domestic dimension market.

MARKETING

Markets for wood products that could be produced in coastal Alaska have been difficult and slow to develop. The small population of Alaska, 302,647 in 1970 (Lin 1971), will not support significant and efficient woodworking plants, even if those plants could capture most of the Alaska market. In the past, small sawmills could produce the lumber needed for fish boxes and local construction. The larger, efficient mills of today must have export markets. In 1962, the per capita consumption of lumber in the Nation was 200 board feet. At this rate of use, Alaska would require about 60 million board feet of lumber annually. Southeast Alaska has seven mills, each with capacity to produce the total needs of the Alaska population. In order to operate as they do, these mills contract their output to a foreign market, and Alaskans obtain their lumber needs through "lower 48" wholesalers.

Export markets have been slow to develop, partly at least because of the high cost of transportation. In the past, specialty items such as spruce for airplane stock could be exported because of the high value. Standard lumber products, however, have not been able to compete in the Pacific Northwest markets. Many people did and still do argue that because the Jones Act restricts shipment of goods between United States ports to United States vessels, it is unfair to Alaska (Johnson and Jorgenson 1963).[15] It is claimed that this restriction on shipping adds to the cost of goods delivered to Alaska, thereby adding to the costs of production in Alaska and to the cost of products shipped from Alaska to United States markets.

In a study of the economy of Haines, Alaska, Massie and Haring (1969) concluded that "The isolated location of the Haines community and the existence of unattractive domestic shipping costs have to date limited profitable sales of forest products from Haines to a one buyer market--Japan."

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[15] Robert K. Buchanan. The history, growth, use, and future development of the timber industry in southeastern Alaska. Thesis on file at the Pacific Coast Banking School, University of Washington, Seattle, 129 p., illus., 1972.

The development of foreign markets, primarily Japanese, made it possible for Alaska to compete with industries in any other State. Cost of production in Alaska might still be higher, but at least transportation to the market was competitive. Because Alaska was hungry for industrial development, the Japanese markets were welcomed.

Another restriction on market development was the policy that requires primary manufacture of Alaska Forest Service logs in Alaska. It is often argued that logging of southeast Alaska forests would have increased much earlier if the logs could have been rafted or barged to mills in the Seattle-Tacoma area. How the wood markets of southeast Alaska might have developed under a different policy will, of course, never be known. However, Alaskans seem to generally favor the current policy. This was apparent during hearings regarding the Foreign Assistance Act of 1968 (U.S. Congress 1968a, 1968b, 1968c). In fact, the State has followed the same policy on timber sold from State lands. Based on limited data, Massie (1969) found that round log export from privately owned timber provided greater gross revenues per unit of wood than cant manufacture.

The wisdom of selling Alaska's wood products to Japan is often questioned. If free enterprise by American investors is to be encouraged, it would seem difficult to do otherwise. To require the marketing of Alaska products to "lower 48" markets would be selective action and inconsistent with the feeling of Alaskans with respect to restrictions such as the Jones Act. In a study of the economic ties between Japan and Alaska, Tussing et al. (1968) found no indication that Japanese investments and markets have preempted domestic enterprise or markets. Furthermore, there are a number of indications that the foreign markets for U.S. wood products end up benefiting the American consumer as well as forest utilization and management practices. For example, many logs that cannot be sold to U.S. markets are being sold to Japan rather than being left in the woods to rot. By selling logs to Japan, U.S. consumers possibly get lumber at a more favorable price from Canada--lumber that otherwise might go to Japan. In the Pacific Northwest, the Japanese market for small logs and chips is making it possible to commercially thin some stands and thereby increase the productivity of the residual stands. Without such markets the thinning would not be done. The Japanese market provides an opportunity to harvest overmature stands in southeast Alaska and thereby convert them to more productive young stands.

In 1961 it was estimated that 93 percent of Alaska's total output of wood products left the State. Of the total production, 57 percent went to foreign markets and 36 percent to U.S. markets (Bones 1963). A 1966 estimate showed little change in the proportion of product output going to a foreign market (Massie 1967).

All pulp is exported from Alaska. In 1973 Japan received about 34 percent (based on value) of the pulp production (table 15), while 2 percent went to other foreign markets and 64 percent to "lower 48."

TRENDS

Except for stands that are being cut, the inventory volume of southeast Alaska forests is rather stable. Of the commercial forest area of southeast Alaska, 87 percent is in old-growth stands in which growth and mortality are offsetting. Thirteen percent of the forest is in young stands that are growing at a reasonable rate.

Cutting has been increasing. Although early records were not kept, it is known that in the era of 1950 and before, less than 2,000 acres were cut annually. By 1955 the cut increased to about 5,000 acres per year, to 10,000 by 1962, and to 16,000-17,000 acres by 1971. When full allowable harvest is reached, about 30,000 acres will be required annually.

A better record has been kept of the volume of log production. Log production (fig. 14) has, of course, followed basically the same trend as area cut. In 1970 the timber volume harvested was about eight times greater than in 1950. Since 1960, log production has been increasing at a rate of about 6 percent annually.

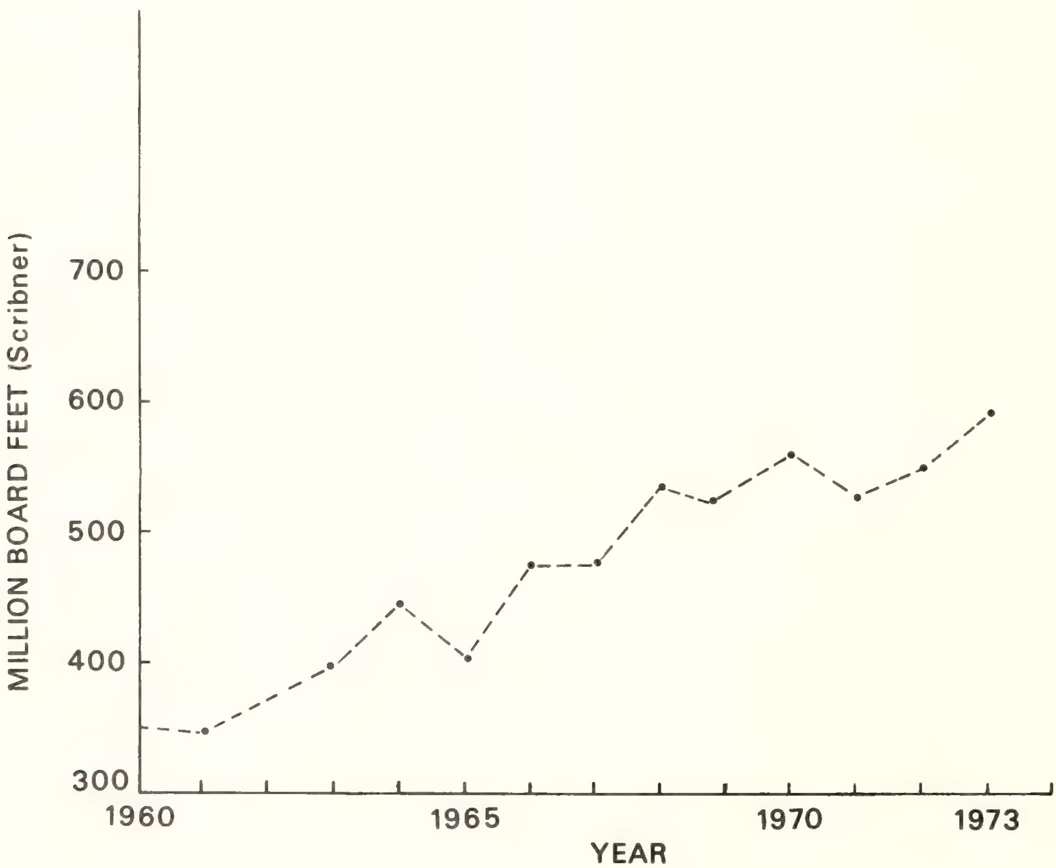

Figure 14.--Log production from Alaska National Forests, 1960-73.

Pulp production has increased from less than 300,000 tons in 1960 to roughly 400,000 tons in 1971. However, pulp production has tended to level off since 1963 when the mills nearly reached capacity. The next large increase in pulp production should take place with the building of a new mill to process timber sold to the Champion International Corporation. Building this third plant could increase total pulp production to 600,000 tons.

Lumber production has been increasing, but here again, good records are not available. Bones estimated lumber and cant production at 70 million board feet for 1961. Massie estimated 158 million for 1966 and Snyder, 296 million for 1968. Beginning with its May 1963 issue, *Forest Industries* has been reporting the production of major mills. Response to the *Forest Industries* questionnaire from Alaska was not good in the beginning but has been good in recent years. The indicated total production for southeast Alaska sawmills in 1973 is 440 million board feet. From 1967 to 1973, lumber and cant production in southeast Alaska increased an average of about 16 percent per year.

Under present Forest Service projections, the harvest will increase until about 1980 and then level off at the accessible annual allowable harvest. The inventory volume will steadily decline until about 2020, at which time the inventory volume will amount to about 70 percent of the current inventory. With removal of the old-growth stands, mortality will gradually decline. Cutover areas will begin producing measurable board-foot volume within 30 years after cutting, and by 2025 net growth will exceed the amount being cut (fig. 10).

If demand for timber should increase to the level that currently inoperable commercial forest land can be harvested, an alternate cutting plan might be adopted. One such schedule would reduce the current inventory to about 52 percent of the initial volume base by 2020. The cut would increase gradually each year, but growth would increase at a faster rate. However, because by 2020 nearly 50 percent of the inventory would still be in old-growth sawtimber stands that contribute very little net growth, the net annual growth of the total forest at that time would equal about 55 percent of the annual volume removed. Growth and removals would equate in later years as more of the old-growth stands are converted to vigorous young-growth stands.

NEEDED INVENTORY, ECONOMICS, and MARKETING RESEARCH

INVENTORY

Thus far Forest Survey work has generally been based on the need for timber resource information useful in regional and national planning. A two-phased system of sampling information observable on aerial photos and measured on field plots has been used. The system gives good information for a forest and its major planning units. Information gathered is used to describe the timber production opportunity, to determine the allowable annual harvest, and to prepare long-range plans.

The current inventory program has not satisfied the land manager's need for bookkeeping records of forest conditions and management actions on land units. Past inventories have not related timber resource data to the many basic land strata employed by the manager in his multiple use plan. To do this requires a more intensive inventory system that can be tied to specified mapped areas or coordinates and is capable of being recorded, recalled, and summarized quickly by computer methods.

As demonstrated in other regions there certainly is a need for intensive inventories at the management unit level. Such inventories are expensive and take much time. They cannot be repeated on a short enough time interval to provide total change data for regional and State planning. It appears that inventories at two intensity levels are needed, one for the local land manager and one for regional, State, and national planning.

Much progress has been made in the techniques of timber inventory, but much room for improvement remains. More use of high altitude photography, photo interpretation, and computer methods might greatly reduce the cost. Methods of projecting change in the total forest without total remeasurement of field plots should be researched. A better tie to land productivity classes is needed. Relating timber inventory to major soil types may be part of the answer. However, such a system will not work until reliable soil type maps are available for the region. Some success has been achieved in mapping major soil types from aerial photos.

Total resource inventories are needed to aid in multiple use planning. Some progress has been made in developing techniques to gather timber inventory and other resource data at the same time, but more effort and time need to be given to this problem. In an agency such as the Forest Service, where multiple use planning requires knowledge of water, recreation, soils, insects, disease, timber, wildlife, fish, minerals, and other resource factors, much of the information needed could be gathered in one well-planned multiresource inventory. Systems for doing this need to be developed. Public Law 93-378, the Forest and Rangeland Renewable Resources Planning Act of 1974 enacted by the 93d Congress, now authorizes and directs the Forest Service to undertake this work. The first assessment of all renewable forest and rangeland renewable resources is to be completed in 1975.

Definition and identification of criteria for land and stand condition classes used in forest inventory are a continual problem. Classes that are based on economic criteria are especially troublesome because such factors are continually changing and because people motivated by different objectives cannot agree on application of the economic criteria. One clear example is the classification of operable and inoperable commercial forest land. Many factors enter into the determination of these two classes. The logging operator strives to maximize profits, so naturally wants the best quality timber on the easiest logging situation that is obtainable. The forest manager is concerned with harvesting the highest risk stands first and with protecting water, land, and esthetic values. Seldom will the logging operator and forest manager agree. They are continually bargaining.

To the extent that it can be done, inventory personnel have classified forest land into commercial operable and commercial inoperable classes based on current logging methods and costs. The operable commercial forest land becomes the base for determining allowable annual harvest from the forest. Because the criteria are intended to be current, the logging operator's immediate costs and profit margin become related to the allowable harvest of the forest. In bargaining situations between the operators and forest managers regarding timber sale boundaries, logging costs and operability limits immediately become limiting factors and disagreement can be expected.

Forest management decisions aimed at long rotations, such as 100 years in southeast Alaska, will always carry uncertainties. However, in such a long period there will be many opportunities for management adjustments. Perhaps

the operability classification should be projected to some future time, such as a fourth or half of the rotation period. The forest manager and logging operators would still have the problem of determining currently operable sales. But the manager would not be faced with immediate adjustments in his rotation plan. These could be made periodically, based on study of historical information. This and other possible solutions to the problem of operability classification should be studied.

ECONOMICS AND MARKETING

A large and growing tourist industry is attracted to Alaska partly because of the unequaled scenic grandeur of southeast Alaska's forests, water, and associated animal and aquatic life.

Many conflicts have developed in recent years between those bent on industrial use of natural resources and those interested in preserving the intangible values. That both are needed is beyond question. The policymaker needs estimates of the values involved and how restrictions on one may affect the other. As a State, Alaska must have income from a stable tax base. Many tourism activities are seasonal, and investments are based outside the State. Income to the State must come from taxing home businesses that cater to the tourists. Research is needed to tell policymakers how this compares with the tax base provided by year-round industries.

Based on value, 50 to 70 percent of the pulp and lumber production of southeast Alaska is exported, mostly to Japan. Alaska imports its lumber needs from the "lower 48." Because stumpage purchases are dominated by two pulpmills, a truly competitive market for stumpage does not exist. Because of the peculiar interlocked markets, it is difficult to obtain end product values that can be carried back to log values for stumpage appraisal purposes.

The economy of Alaska is developing under restrictions--some aimed at helping Alaska, others not. Examples are the Jones Act which restricts shipping without Alaska interests in mind and the primary timber processing policy aimed at promoting industrial development in Alaska. Some of these policies may outlive their usefulness. The State could benefit from an objective study of the marketing and utilization alternatives and the probable long-range effects of following the various alternatives. Would log export, at least on a limited basis, help southeast Alaska's timber markets and help establish competitive stumpage values? Should wood chips from stumpage sales qualify for export? Would such policy changes encourage more complete utilization? In the past an exception has been made to allow the export of cedar logs harvested during clearcutting operations to obtain western hemlock and Sitka spruce. Without this exception, the cedar logs would not have been utilized. Now western redcedar, as well as Alaska-cedar, has become a valuable tree in high demand. Should the export of cedar logs continue? Because markets and the economy are dynamic, we need to continually study the alternative policies and determine when changes should be made. Better utilization of the resource might result from less restriction on trade. On the other hand, less restriction might result in diseconomies to the State or the Nation.

Transportation economics is critical to southeast Alaska development. Systems are changing--and improving. Goods that once arrived in Alaska by ship are now containerized and delivered by tug and barge. The freight ship once familiar in Alaska's coastal waters has been retired or transferred to other service. But like the ships, the barges arrive loaded and generally return

empty. Backhaul products could greatly reduce freight rates. The Alaska Marine Highway or ferry system, developed in recent years, has changed southeast Alaska's transportation pattern. Highways to communities of southeast Alaska and to British Columbia are either under construction or being planned. Our knowledge of the implications of this growth and change in transportation for policy decisions has not kept pace. It would appear that some new market opportunities should become available. Included in transportation economics are the methods of moving logs from the woods to the mills. The present log rafting system results in heavy losses of logs at times, which may be difficult to justify on strictly a transportation cost basis. If water transportation of logs should shift to barging, then an entirely different logging road system would be required. Based on cost, however, a recent study shows that in most cases rafting is the most economical means of transporting logs in southeast Alaska.[16]

Factors of efficiency and world markets require study and better understanding. The two subjects are related to the extent that world markets usually require high production plants, whereas home markets might be small by comparison. Southeast Alaska presently depends on export markets for its timber industry. Clearcutting to supply timber for the southeast Alaska industry is the preferred forestry practice. The size of areas clearcut can be varied, and here economics of scale apply. The costs, both real and social, are different for 1,000 acres cut in 20-acre tracts than for 1,000 acres cut in one block. Understanding these and other costs will help improve policy decisions with respect to harvesting and other use practices.

How much timber per acre and what size are needed for a commercial operation? How much can be invested periodically to grow timber over various rotations? The economics of growing timber in southeast Alaska have not been studied. The base for commercial forest land classification is 20 cubic feet of mean annual increment. Although the Forest Service does not agree, currently some logging operators claim that any acre with less than 20,000 board feet is not economically operable. These bases change over time and presently are not derived from sound economic studies. Fertilization, thinning, and other cultural treatments to improve growth rates or quality are being considered without knowing the cost-benefit relationship. These questions are important both to the land manager who must decide how to invest money and to the Nation in forecasting supply.

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[16] Kenneth E. Beil. The economics of rafting vs. barging as a means of transporting logs in southeast Alaska waters. Unpublished report to Pacific Northwest Forest and Range Experiment Station under contract No. 19-200, 53 p., 1974.

EPILOG

Alaska is still in the category of a new area for settlement. The magnitude of the new industries, recreational opportunities, wilderness experiences, and other uses that Alaska's forests can support is still unknown. How many citizens of the United States can benefit from development of these forest resources depends upon policies as well as upon inventory and evaluation of the resources and research to direct their use.

Because the amount of money allotted to forest research is limited, there must, of course, be a priority for its use. Forest inventory and economics research in Alaska should carry a high priority because:

1. Forests of Alaska, and southeast Alaska forests in particular, are a major key to the potential development and growth of the State.

2. The number of people employed in forest industries of Alaska depends upon markets obtainable, harvesting methods used, products produced, and the extent of secondary manufacture done locally.

3. The manner in which Alaska's forest land is to be used has national interest, and the outcome may affect the jobs and interests of people along the Pacific coast and elsewhere.

4. Forest inventory and economics research should and can provide the needed look ahead and thereby play a major role in allocations of Alaska's forest resources to meet the often conflicting environmental, social, and industrial demands of the people. That opportunity is present now.

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APPENDIX

DEFINITION OF TERMS

Land Use Classes

Forest land.--Includes (a) lands that are at least 10 percent stocked by trees of any size and capable of producing timber or other wood products, or of exerting influence on the climate or on the water regime; (b) land from which trees have been removed to less than 10-percent stocking, and which has not been developed for other use. (Forested tracts and islands of less than 10 acres and isolated strips of timber less than 120 feet wide are excluded.)

Commercial: Forest land which is (a) producing or capable of producing usable crops of industrial wood (will net a minimum of 8,000 board feet per acre, International 1/4-inch rule); (b) economically accessible now or in the foreseeable future; and (c) not withdrawn from timber utilization.

Noncommercial: Forest land incapable of producing usable industrial wood because of adverse site conditions or withdrawn for specified purposes.

Unproductive: Noncommercial forest land which does not now support or will not produce a minimum of 8,000 board feet per acre.

Productive: Forest land capable of producing usable crops of industrial wood, but withdrawn for specified purposes through statute, ordinance, or administrative order.

Nonforest land.--All land not qualifying as forest land. Includes land which has never supported forest growth; land from which the forest has been removed to less than 10-percent stocking and has been developed for other use, such as agricultural, residential, or industrial; all land in thickly populated urban and suburban areas; and water areas under 40 acres classified by the Bureau of the Census as land. Glaciers, icefields, marshland above mean high tide, permanent brush fields, muskegs less than 10-percent stocked to trees of any size, and barren mountaintops are examples of lands which have never supported forest growth.

Forest Types

Forest types are classified on the basis of the species or species group that accounts for the major portion of the stand in terms of net board-foot volume for sawtimber, cubic-foot volume for poletimber, and number of trees for seedling-sapling stands.

Sitka spruce: Forests in which Sitka spruce is predominant.

Hemlock-Sitka spruce: Forests in which 50 percent or more of the stand is western hemlock but in which Sitka spruce makes up 30 to 49 percent of the stand.

Hemlock: Forests predominantly western hemlock except when Sitka spruce comprises 30 to 49 percent of the stand.

Hardwood: Forests predominantly cottonwood or red alder, singly or in combination.

Tree and Stand Classes

Sawtimber trees.--Live trees of commercial species, at least 11.0-inch d.b.h., with at least 25 percent of their gross board-foot volume free from rot or other defect and that contain at least one merchantable saw log.

Merchantable saw log: For softwoods, not less than 16 feet long, containing a minimum of 20 board feet, between a stump height equal to d.b.h. but not exceeding 4-1/2 feet and a merchantable top equal to 40 percent of d.b.h., except in the case of small trees where the minimum top is 6 inches. For hardwoods, not less than one 8-foot log to a minimum top of 8 inches d.i.b. for small trees and 40 percent of d.b.h. for large trees. After deductions for defect, a saw log must contain a net scale of at least 33-1/3 percent of the gross.

Upper stem: The section of the bole or main stem of a sawtimber tree from the merchantable top to a minimum top diameter of 4.0-inches inside the bark.

Poletimber trees.--Live trees, 5.0-inches to, but not including, 11.0-inch d.b.h. These trees are of sufficiently good form and condition to indicate that they will grow into merchantable sawtimber trees.

Sapling and seedling trees.--Live trees of commercial species, less than 5.0-inch d.b.h., and of sufficiently good form and vigor to indicate that they will grow into merchantable sawtimber trees.

Growing-stock trees.--All live trees, except cull trees, of commercial species.

Cull trees.--Live trees, 5.0-inch d.b.h. and over, that do not qualify as sawtimber or poletimber trees due to poor form, limbiness, rot, or other defect. Rotten cull trees contain excessive decay. Sound cull trees have excessive crook, sweep, or large limbs.

Salvable dead trees.--Standing, dead, sawtimber-size trees containing at least one merchantable saw log having sound volume equal to at least 50 percent of the gross volume in the tree.

Mortality trees.--Trees, 5.0-inch d.b.h. and larger, which died of natural causes and were not cull trees at the time of death.

Sawtimber stand.--Forest stands in which the minimum volume for coniferous types is 8,000 net board feet per acre in growing-stock trees, 11.0-inch d.b.h. and larger. For hardwood sawtimber stands the minimum volume is 4,000 net board feet per acre.

Old growth: Sawtimber stands in which the majority of volume is in sawtimber trees more than 150 years of age.

Young growth: Sawtimber stands in which the majority of volume is in sawtimber trees less than 150 years of age.

Poletimber stand.--Stands failing to meet the sawtimber stand specification, but at least 10 percent stocked with poletimber and larger growing-stock trees, and with at least half the minimum stocking in poletimber trees.

Sapling and seedling stand.--Stands not qualifying as either sawtimber or poletimber, but having at least 10-percent stocking of trees of commercial species and with at least half the minimum stocking in seedlings and saplings.

Nonstocked and other areas.--Commercial forest land less than 10 percent stocked with growing-stock trees.

Volume Classes

Sawtimber volume.--The net volume in board feet, International 1/4-inch rule, of merchantable saw logs in live sawtimber trees of commercial species.

Growing-stock volume.--The net volume in cubic feet of sound wood in live sawtimber and poletimber trees of commercial species from the stump to a minimum 4.0-inch top inside the bark.

Total volume.--The net volume in cubic feet of sound wood in live and salvable dead sawtimber and poletimber trees and in sound and rotten cull trees of commercial species from the stump to a minimum 4.0-inch top inside the bark. Included is the volume of hardwood limbs on sawtimber trees to a minimum diameter of 4.0 inches inside the bark.

Log Grades

Sample western hemlock and Sitka spruce trees were graded in 16-foot log lengths. However, when any 12- or 14-foot section of a log was better than the entire log, the grade of the shorter section was given to the entire log.

The rules used were from the January 1954 edition of Official Log Scaling and Grading Rules for the Puget Sound, Grays Harbor, Southern Oregon, and Northern California Bureaus.

Abbreviations Used

DBH, d.b.h., or b.h.--Abbreviation for diameter at breast height. This measurement is taken 4-1/2 feet above the ground on the uphill side of the tree.

D.i.b.--Abbreviation for diameter inside the bark. This measurement may be taken at any specified location.

D.o.b.--Abbreviation for diameter outside the bark. This measurement may be taken at any specified location.

Two-inch diameter class.--If the classes are expressed as 6, 8, 10 inches, etc., this means that the diameters included are from 5.0 through 6.9, 7.0 through 8.9, 9.0 through 10.9, etc.

Stocking Classes

Stocking is a measure of how effectively the area is being utilized by growing stock. No stocking measure was assigned to old-growth stands. For young-growth stands, ocular estimates were made of the crown cover of sawtimber trees on the 10 acres surrounding each plot location. The stocking of poletimber, saplings, and seedlings was based on the number of stems per acre. For poletimber, these were:

	Percent stocked
210 or more stems per acre	70
120 to 210 stems per acre	40
30 to 120 stems per acre	10

For saplings and seedlings, stocking was measured on ten 4-milacre circular plots. Two or more established saplings or seedlings were required to stock a 4-milacre plot. Stocking of the area was determined by the number of 4-milacre locations that were stocked. Thus, if six of the ten 4-milacre locations were stocked, the area was judged to be 60 percent stocked.

Area stocking classes	Percent
Nonstocked	0-10
Poorly stocked	10-39
Medium stocked	40-69
Well stocked	70-100

Volume Measurements

Board foot.--A board 1 foot long, 1 foot wide, and 1 inch thick. The bark is usually eliminated from this measurement. In practice, the working unit is 1,000 board feet and may be abbreviated to M bd. ft., M bm, M.B.M., or MBF.

Cubic foot.--A cube 12 inches on a side. The cubic-foot volume of a log or tree is commonly computed by Smalian's formula (Bruce and Schumacher 1950).

International 1/4-inch log rule.--A rule used to determine the log volume in board feet (Bruce and Schumacher 1950).

Allowable Cut

The volume of wood which can be cut under management for a given period of time.

A number of formulas are available to make this estimate. The Kemp formula is easy to apply with the kind of inventory data available. Usually this formula is applied to areas in which there is a surplus of timber beyond rotation age. The objective is to determine the cut that will achieve an approximately equal distribution of area by age or stand-size classes within a rotation.

The Kemp formula:

$$\text{Annual cut} = \frac{7A + 5A_1 + 3A_2 + A_3}{4R} (MA)$$

A = area of sawtimber stands
A_1 = area of poletimber stands
A_2 = area of seedling and sapling stands
A_3 = nonstocked area
$A + A_1 + A_2 + A_3$ = total commercial forest land area
R = rotation in years
MA = average volume per acre of current sawtimber stands, the A stratum.

EQUIVALENTS

English	Metric
Length:	
1 mile	1.609 kilometers
1 rod	5.029 meters
1 foot	30.480 centimeters
1 inch	2.540 centimeters
Area:	
1 square mile	2.590 square kilometers
1 acre	0.4047 hectare
1 square foot	0.093 square meter
1 square inch	6.451 square centimeters
Volume:	
1 cubic foot	0.0283 cubic meter
1 cubic inch	16.3871 cubic centimeters
Weight:	
1 short ton	0.907 metric ton
1 long ton	1.016 metric tons

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1975
USDA FOREST SERVICE GENERAL TECHNICAL REPORT PNW-35

Guidelines for Roadless Area Campsite Spacing to Minimize Impact of Human-Related Noises

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GUIDELINES FOR ROADLESS AREA CAMPSITE SPACING TO MINIMIZE IMPACT OF HUMAN–RELATED NOISES

Reference Abstract

Dailey, Tom, and Dave Redman.
1975. Guidelines for roadless area campsite spacing to minimize impact of human-related noises. USDA Gen. Tech. Rep. PNW-35, 20 p., illus.

This report offers guidelines for campsite spacing and location in roadless areas to allow several levels of insulation from noise impacts between camping parties. The guidelines are based on the distance that different human-related noises travel in a variety of outdoor settings. The physical and psychological properties of these noises are described and discussed. The effects of different environmental features--ridges, hills, dense woods, low vegetation, still water--on noise transmission are also described. General management actions are suggested for locating camps to minimize intrusive noise from other camping parties.

Keywords: Campsite spacing, amenity values (forest).

RESEARCH SUMMARY
General Technical Report PNW–35
1975

The desirability of campsites in roadless areas is affected by the degree of insulation the site affords from noise of other camping parties. Research suggests that this insulation is most important in hard-to-reach areas where few contacts with other parties are expected or desired. Campsites which are easily accessible are generally more popular and campers expect less isolation. These differences in visitor expectations and desires suggest there should be corresponding variation in spacing guidelines to achieve varying degrees of isolation. Three sitations--"portal," "primitive," and "pristine"--offering increasing opportunities for noise insulation between camps are proposed.

The distance a noise is audible depends on (1) the intensity and frequency of the noise, (2) the presence of environmental features between the source and the receiver of the noise which may attenuate the noise, and (3) the background noise level.

The greater the intensity (loudness) of a noise and the lower its frequency (pitch), the farther it will travel. Field measurements of a variety of human-related noises showed that the loudest were gunshot (136 dBC), yell (78 dBA), safety whistle (76 dBA), and trailbike motor (74 dBA). All measurements were at 50 feet from the noise source. Lowest frequency measurements were obtained for guitar and trailbike.

As any noise spreads from its source, its intensity will decrease at a predictable rate. In addition, intensity may be further decreased by certain features of the environment through which the noise travels. The most effective are rigid barriers--hills, ridges, rises, and dense woods. Low vegetation has little attenuating effect, and a still water surface has virtually no effect.

Naturally, the quieter the background noise level against which an intrusive noise is projected, the greater the range over which the noise will be audible.

Background noise level, under low wind conditions, in a mature coniferous forest is 35 dBA and about 30 dBA in an alpine meadow. Near the bank of a small stream, noise level is 45 dBA. An intrusive noise must be reduced 15 dBA less than the background noise level before it becomes indistinguishable.

Spacing requirements for settings with different background noise levels and combinations of environmental features are presented in table 1 for each of the three situations. The spacing requirements are designed to achieve a certain standard of insulation in each situation.

General guidelines for campsite location include taking maximum advantage of environmental features, such as woods and hills, which lessen noise transmission between camps and, where possible, locating sites near areas with high background noise levels. From the standpoint of noise insulation, lakeshores and meadows are poor locations for campsites.

Table 1.--*Summary of spacing requirements for pristine, primitive, and portal situations*

Standard of insulation	Setting	Threshold level	Space requirements (approximate)
		---*dBA*---	----*Feet*----
Pristine situation:			
No sounds less than 78 dBA audible between camps (Human yell)	Meadow	10	20,000
	Woods	20	9,600
	Lake-woods[1]	20	9,600
	Meadow with barrier	10	6,400
	Stream and woods	30	3,200
	Woods with barrier	20	1,600
Primitive situation:			
No campsite noises less than 60 dBA audible between camps (Singing)	Meadow	10	4,200
	Woods	20	1,450
	Lake-woods[1]	20	1,450
	Meadow with barrier	10	950
	Stream and woods	30	600
	Woods with barrier	20	400
Portal situation:			
No campsite noise less than 48 dBA audible between camps (Conversation)	Meadow	10	1,950
	Woods	20	500
	Lake-woods[1]	20	500
	Meadow with barrier	10	250
	Stream and woods	30	250
	Woods with barrier	20	200

[1]These spacing requirements between camps at lake sites surrounded by woods are applicable only when the camps are located at least 250 feet from the lakeshore. This location affords both auditory and visual screening by the woods which are not available when camps are situated at the lakeshore.

Contents

Introduction

Increasing recreational use of roadless areas--whether legally designated or de facto wilderness--is creating new management challenges. The conflicting goals of accommodating more visitors and insuring quality recreational experiences demand knowledge, not only of the visitors' expectations but of their physical and psychological impacts upon each other. These impacts are most critical near campsites where visitors spend much of their time and where their desire for solitude may be greatest (Hendee 1967, Stankey 1973).

Several recent studies[1/] indicate that most campsites in Wilderness and backcountry have been informally established by the campers themselves, and at popular locations they are frequently close to each other. Perhaps this is the result of unplanned growth over time without formal consideration of the many factors that can affect the experience of separate parties of users. However, some managers are now seeking to relocate overused campsites and disperse users. In so doing they have the opportunity to consider the many factors--including noise insulation--which are important to campsite location and affect user experience.

This report offers guidelines for campsite spacing to achieve varying degrees of insulation from noise between camping parties. The guidelines are based on field tests of the intensity and frequency of different human-related noises and on acoustical research on the effect of different environmental features on noise transmission. This is basic information for wilderness and backcountry managers faced with the problem of determining levels of use desirable to increase visitor enjoyment of these environments.

Assumptions

Underlying this study are four basic assumptions relating the "wilderness" experience to the need for adequate space between campsites to preserve these qualities. Most of the studies upon which these assumptions are based have focused on visitors to legally designated Wilderness Areas. However, it seems likely that roadless area recreationists seek similar experiences whether their trip is into a designated or de facto wilderness.[2/]

[1/] Russ Koch and John Hendee. Recreation sites on the Pacific Crest Trail-Junction 2000/951 (Cougar Valley Trail) to Fish Lake, Naches Ranger District, Wenatchee National Forest. Unpublished manuscript, 9 p., 1975.

Dan Wood. Public use of Forest Roads pilot study, 1974, Deschutes National Forest, Bend and Sisters Ranger Districts. Unpublished manuscript, 20 p. plus appendix, 1974.

Both available from U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station, 4507 University Way NE, Seattle, Wash. 98105.

[2/] Throughout the paper, wilderness, backcountry, and roadless areas will be used interchangeably.

1. Roadless area visitors seek solitude and isolation from nonparty people. Wilderness is legally defined, in part, as providing "outstanding opportunities for solitude"(U.S. Congress 1964). A number of studies of wilderness use and users have demonstrated the importance of solitude (minimal contact between camping parties) as part of the wilderness experience. For example, reporting the results of a survey of almost 500 visitors to four Wilderness Areas, Stankey (1973) concluded that "most visitors consider low intensities of use, involving only few encounters, as an important dimension of the wilderness experience." Hendee et al. (1968) found that a strong preference for solitude among users of three western Wilderness Areas was an attribute which differentiated "wilderness-purists" from more urban-oriented wilderness users. Other studies (Lucas 1973, Burch and Wenger 1967, Hendee 1967) have reported similar findings. Solitude has been demonstrated to be an important feature of the wilderness experience, especially for those visitors holding a "purer" concept of wilderness.

2. The perceived impact of auditory and visual encounters between parties is especially great at campsites. This assumption is supported by two major studies indicating that over 65 percent (Stankey 1973) and 72 percent (Hendee 1967) of visitors to a total of six western Wilderness Areas favored campsites "out of sight and hearing" of other visitors, with an even higher percentage of purist users feeling this way. According to Stankey (1971) the campsite represents the user's "territory," and social interaction with other parties is not welcome in the camp. Campsite location relative to other camps is of more importance to the visitor's experience than is camp location relative to trails. Stankey's (1971) work has shown that "persons passing by the camp... do not create the level of disturbance that a party which establishes their camp nearby does" (p. 160).

3. The distance that human-related noises travel indicates necessary campsite spacing requirements to minimize between-party impacts. In most outdoor settings, auditory stimuli are detectable over a wider range than visual stimuli. Vegetation and relief which can completely screen visual contact between parties might only partially reduce auditory impacts. In addition, sound tends to intrude more.

4. Abundant spacing between campsites is most critical in the "interior" as opposed to "peripheral" portions of a roadless area. Research (Stankey 1973) indicates that encounters near the trailhead are more expected and therefore more tolerated than encounters in the interior. This is supported by wilderness use data indicating that concentrations of users on trails and near the periphery drop sharply as the distance covered increases.

This evidence suggests that the farther removed a camping area is from the trailhead, the more important it is in terms of visitor satisfaction that the campsites be spaced to allow most "people" noises to be screened out.

For the purposes of the present study, three distinct situations are recognized--portal, primitive, and pristine--offering increasing opportunity for auditory and visual isolation of camping parties from each other. This informal categorizing assumes that visitors place themselves according to their abilities, orientations, and desired experiences--and have different expectations for solitude and isolation in each situation.

Studies indicate that users differ in their desire for solitude and seclusion (Hendee et al. 1968, Stankey 1973). Some users, purists, seek greater isolation from other visitors and reminders of civilization. Others are willing to accept some degree of contact in more accessible locations. Using the space required by purists as the standard throughout a roadless area may only hasten the day when all use must be restricted. On the other hand, uniform standards appropriate for less discriminating users will degrade the experience sought by the purist.

It seems best to provide a continuum of campsite spacing standards, whose application depends on practical considerations of accommodating increasing numbers of visitors near the edge of a roadless area and providing greater campsite solitude for those willing to seek it out in the interior.[3]

Objectives

The objectives of this study were to: (1) describe the physical and psychological properties of various human-related noises, (2) determine the effect of environmental conditions such as land forms and foliage on noise transmission, and (3) recommend guidelines for campsite spacing and location based on (1) and (2).

We examined 11 human-related noises often associated with roadless area recreation. These included:

1. trailbike motor (1974 Honda TL 125),[4]
2. safety whistle,
3. conversation (four persons),
4. singing (four persons),
5. yelling (one person),
6. gunshot (30.06 rifle),
7. clattering pans,
8. guitar,
9. harmonica,
10. pounding tent stakes, and
11. chopping wood.

---

[3] The concept of distinct situations as defined and developed in this paper is presented as a hypothetical abstraction rather than a policy recommendation. We do not imply that all three situations should be contained within a Wilderness. We do, however, encourage recognition of the research findings we have cited which suggest that visitors' expectations for solitude vary directly with the distance they have hiked from the nearest road.

[4] Mention of product by name does not imply endorsement by the U.S. Department of Agriculture.

These sounds were all "intrusive" as opposed to those "natural" background noises one would expect to find outdoors, such as running water, rustling of leaves stirred by the wind, birds singing.

There are three factors which determine how far the intrusive noise will travel before it is "masked" by the background noise level (Harrison 1974b). These are:

1. the loudness and pitch of the intrusive noise,
2. the presence of environmental factors such as landform barriers or trees which can decrease the loudness of the intrusive noise, and
3. the loudness and pitch of the background noise.

In addition to these physical characteristics of noise and the environment, the psychologically perceived intrusiveness of the noise must also be given consideration.

First we discuss physical and psychological properties of intrusive noise, environmental conditions which can reduce noise level over distance, and properties of the background noise. Finally, we offer spacing standards for campsite location in roadless areas and general guidelines for locating camps to minimize auditory impacts.

Physical Properties of the Human-Related Noises

In this section we discuss the nature of the physical properties of noise and present data describing what these properties are for the 11 noises we studied.

A noise may be described in terms of its intensity and frequency. Basically, intensity refers to how loud a noise is, while frequency is the "pitch" or tone of a sound. Both affect how a sound moves through the air. The sound pressure level, which is a measure of the intensity, is commonly expressed in decibels (dBA),[5/] while frequency is usually expressed in hertz (Hz).[6/]

In general, the greater the intensity (loudness), and the lower the frequency (pitch), the farther a sound will travel. For example, a loud, low frequency such as a trailbike motor will travel farther than a loud, high frequency such as a whistle.

[5/] Acoustic waves generated by sound are a source of power. The amount of power which passes through an area is the intensity of that sound. Intensity is difficult to measure directly, but the pressure that the wave exerts on an area can be measured on a decibel scale. For this study, the A weighting factor (dBA) of expressing sound pressure level was used. This measure most closely approximates human auditory response to noise.

[6/] Most noises are a complex mixture of a number of frequencies. An octave "represents a band of frequency whose highest component is double that of the lowest frequency component" (Harrison 1974b, p. 3). The frequency of each noise measured was recorded as the octave band having the greatest associated sound pressure level.

We measured intensity with a Bruel and Kjaer, Type 2203, sound level meter. We measured frequency using the sound level meter with an attached octave band filter. All measurements were made according to manufacturer's instructions and at a distance of 50 feet from the source of the noise.

Figure 1 presents the maximum intensity of each of the noises studied. By far, the highest maximum intensity was obtained for a gunshot (136 dBC),[7/] followed by a yell (78 dBA), safety whistle (76 dBA), and a trailbike motor (74 dBA).[8/] The noise level of a trailbike motor could be expected to increase by possibly 10 to 20 dBA when it accelerated. Lowest maximum dBA values were for clattering pans (66 dBA), tent stakes being hammered (66 dBA), chopping of wood (64 dBA), singing (60 dBA), guitar (52 dBA), and conversation (48 dBA).

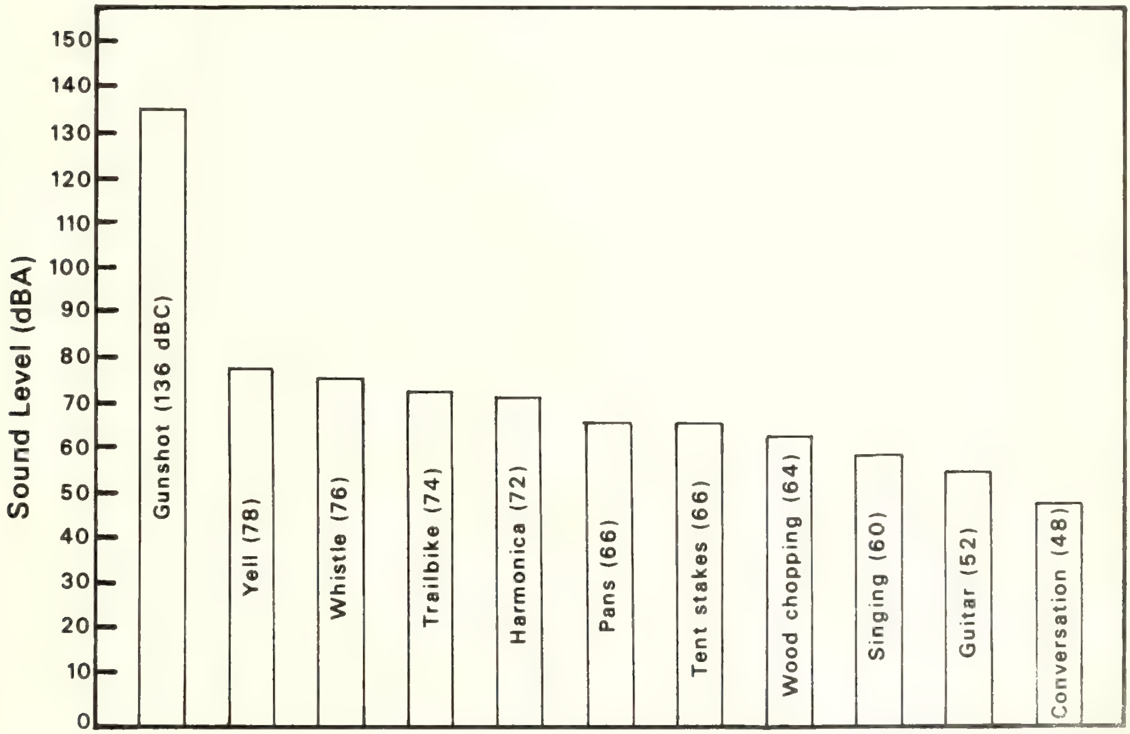

Figure 1.--Intensity of 11 human-related noises measured at 50 feet from noise source.

[7/] Proper measurement of an abrupt noise such as a gunshot requires an impact analyzer which we didn't have. The value reported here on the C weighting scale is from Harrison (1974b).

[8/] The noise level reported for a motorcycle is from Harrison (1974a).

Figure 2 displays the frequencies associated with the noises studied. Highest frequency was recorded for safety whistle (1200 to 2400 Hz) and lowest frequency for guitar (75 to 150 Hz).

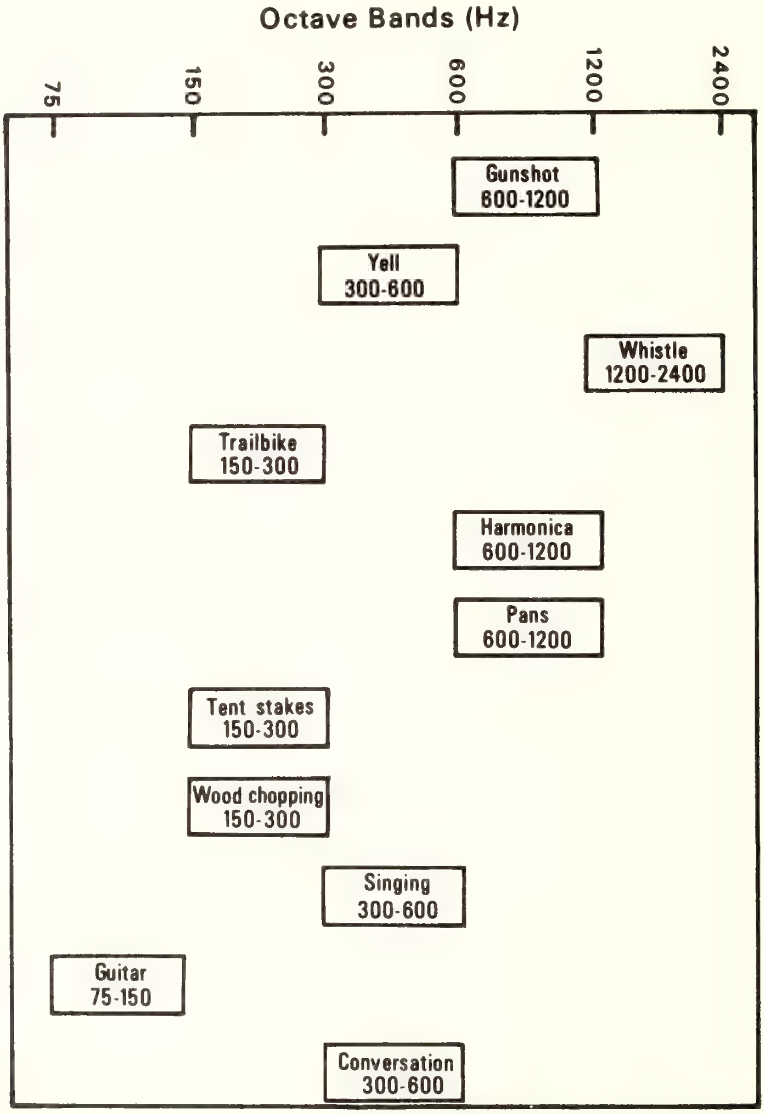

Figure 2.--Octave band frequency of 11 human-related noises.

Psychological Perception of Human-Related Noises

The physical properties of noises are without meaning until they are connected to the way people perceive the noises; knowing that a noise has X intensity and Y frequency does not tell us how annoying it is to the listener. This section outlines those factors which influence the manner in which most humans perceive noise.

There appear to be several physical properties of noise that influence how intrusive or annoying the noise is to a listener (Broch 1969). First, people respond to the intensity, or loudness, of a noise; generally, the louder a sound is judged, the more annoying it is perceived.[9/] Second, the frequency, or pitch, of a noise affects its perceived annoyance. Higher frequency sounds are usually more intrusive than lower frequency. Third, the intermittent reoccurrence of a noise--the drip from a water faucet is a well-known example--affects how annoying the noise is perceived. Noises which are rhythmic, irregular, or intermittent are judged more annoying than continuous noises, even when other properties of the noises are the same.

In summary, noises with some combination of high intensity, high frequency, and/or intermittent reoccurrence are more likely to be perceived as annoying than noises not possessing these physical properties. This suggests that among the noises we considered, rifle shot, motorcycle, whistle, yell, harmonica, and clattering pans would be judged most annoying. However, the annoyance or intrusiveness of a noise is not determined solely by its physical properties. In fact, acoustical research has demonstrated that the connotation or perceived meaning of a noise is more important in determining its effect on the listener than the level of intensity or frequency and duration of the noise (Parry and Stephens 1969).

Obviously, the meaning a noise has depends on where it is heard and by whom. We have discussed the desire for solitude and isolation of most visitors to roadless areas. We have also cited studies which suggest that this desire is greatest at campsites and in hard-to-get-to areas. There, any noise suggesting the presence of other people will probably have a negative, intrusive, or annoying connotation. It is not the physical properties of the noise that account for the perceived annoyance; the noise itself may be barely audible. Rather, it is the meaning of the noise that makes it intrusive. In this case, it means that other people are present where they are neither desired or expected.

In areas where the desire and expectation for complete solitude are not so great, the intrusiveness of a noise may be more dependent on physical properties, intensity, frequency, and intermittent recurrence, so long as the noise is perceived as being appropriate for the setting.

[9/] For most people, a 10-dBA reduction in the sound pressure level results in a noise being judged roughly one-half as loud (U.S. Environmental Protection Agency 1971).

Finally, although absence of annoying noise might be considered a necessary condition for proper campsite location, it may not be sufficient if the source of possible noise is still visible. And even when the noise is audible, visual screening of its source may reduce its impact.[10/]

Noise Attenuation

So far, we have described the physical properties of some human-related noises and discussed the relationship between their measurable qualities and the manner in which people experience the noises.

In this section, we discuss conditions which reduce noise level over distance. First, we offer a general discussion of the meaning of noise reduction. Next, we describe the effectiveness of different environmental factors that reduce noise. Finally, we relate the presence or absence of these factors to the types of environments typically found outdoors.

As any noise spreads out from its source, its sound pressure level will decrease at a predictable rate. The decreasing loudness, or "attenuation," of a noise as it travels through an ideal, loss-free atmosphere is at a rate of 6 decibels for each doubling of distance from the source. This phenomenon is known as spherical spreading (Beranek 1960). For example, a noise measured at 70 dBA 50 feet from the source will be 64 dBA at 100 feet, 58 dBA at 200 feet, 52 dBA at 400 feet, etc.

Outdoors, as noise travels through the air, the sound pressure level measured in dBA is further decreased, i.e., attenuated, by the often combined effects of such factors as dense woods and sound absorption in the air. The factors we examined which are fairly constant and affect attenuation of the sound pressure level include: (1) molecular absorption (sound absorption in the air) (2) rigid barriers (rock outcrops, ridges, etc.), (3) dense woods, (4) low vegetation, and (5) a still body of water (a lake). Several other factors affect how far a sound will travel outdoors, but because of their high diurnal or seasonal variability, they were not considered. These variable factors include the effect of rain, fog, snow, wind, temperature, and turbulence.

ENVIRONMENTAL FACTORS WHICH ATTENUATE NOISE

Sensitive campsite location in backcountry or wilderness areas cannot be solely responsive to rigid guidelines. The wide variety of conditions confronting the campsite planner will often require taking maximum advantage of situations which are less than ideal, where the spacing guidelines we will suggest may be impossible to apply. To do the best with what he has, the recreation manager should be familiar with the relative effectiveness of environmental factors which attenuate noise. These "rules of thumb" are indicated in this section by italics.

[10/] Personal communication with R. T. Harrison, San Dimas Equipment Development Center, San Dimas, Calif.

Molecular Absorption

A sound wave traveling through still air loses energy by a process related to the behavior of oxygen molecules in the air. Compared to the basic effect of spherical spreading, molecular absorption has only a minimal effect on most lower frequency noises. For sounds with a frequency lower than 1,000 Hz (which includes most of the noises we considered in this report) attentuation due to molecular absorption is only about 2 dBA per mile from the noise source (Myles et al. 1971). *Molecular absorption is not a major factor to consider in campsite location to minimize noise impacts.*

Rigid Barriers

The attenuating effect of a large, rigid barrier, such as a rise or a hill, interposed between the noise source and the receiver, depends on two factors: (1) The height of the barrier (the higher, the more attenuation) and (2) the distance between the noise and the barrier (the closer the source to the barrier, the more attenuation). Barrier height is relatively more important in determining attenuation than is the distance between noise source and barrier (Beranek 1960). The lateral extent of the barrier and location of the noise source laterally from the edge of the barrier also affect the level of attenuation. There appears to be a practical limitation on attenuation due to a rigid barrier of about 25 dBA (Beranek 1960). *Rigid barriers such as rock outcrops or hills can be used to reduce auditory impacts between campsites.*

Dense Woods

A sound transmitted through dense woods is absorbed by the leaves on trees and on the ground and scattered by tree trunks and limbs. Studies of the attenuating effect of woods have varying results. It appears than an approximate "excess" (in addition to spherical spreading reduction) attenuation value of about 2 dBA per 100 feet from the source is obtainable under a variety of dense forest conditions (Weiner and Keast 1959, Myles et al. 1971, Eyering 1946, Cook and Van Haverbeke 1972). The maximum excess attenuation caused by forests is 10 dBA for lower frequencies (Myles et al. 1971). *Woods can effectively reduce only low intensity auditory impacts between campsites.*

Low Vegetation

The distance a noise will be transmitted over level terrain with low vegetative ground cover (less than 2 feet high) is highly dependent upon temperature and wind conditions. Decrease is small compared to dense woods or rigid barriers. Minimum attenuation, of course, will be achieved when the receiver is downwind from the noise source. Under still wind conditions, excess attenuation over low ground cover will be only about 1 or 2 dBA at 500 feet from the noise source (Eyering 1946, Harrison 1974b). *Low ground vegetation is not important in decreasing auditory impacts between campsites.*

Still Body of Water

Little research has been conducted on excess attenuation of sound over water. Harrison (1974b) has shown that the total decrease in loudness of noise over a lake surface is actually slightly less than the loss theoretically produced by "spherical spreading." Although the distance a noise will be conducted over water is highly variable depending on wind and temperature gradients, it appears that the excess attenuation created by the still lake surface is about zero. *Water surface between campsites is a liability rather than an asset in reducing auditory impacts.*

COMBINING THE ATTENUATING FACTORS

Outdoors, the foregoing attenuation factors may be combined in a number of ways.[11] For example, attenuation due to molecular absorption occurs in any outdoor environment. To this effect would be added the attenuating effect of dense woods if a dense stand of trees is between the noise source and receiver. In general, the individual noise reduction effects of every factor operating in a particular outdoor setting (including, of course, the basic effect of "spherical spreading") are added together to determine total noise reduction over a given distance.[12]

11/ As previously discussed, attenuation across a lake must be considered as a special case. Reflection of sound from the water surface creates a condition where total noise reduction can best be predicted by determining the attenuating effect of spherical spreading alone.

12/ When the sound level of a given noise is known at a reference distance from the noise source, the total attenuation in the same direction but at a greater distance is given by the equation (Beranek 1960):

$$L_1 = L_0 - 20 \log \frac{r1}{r0} - A_e \text{ decibels}$$

Where L_1 = level (in decibels) at r_1 distance from the source, L_0 = level (in decibels) at r_0 distance from the source, where r_1 is greater than r_0, and A_e = excess attenuation (in decibels).

The excess attenuation, A_e, is determined by the sum of its various contributions which are considered independent of each other:

$$A_e = A_{e1} + A_{e2} + A_{e3} + A_{e4} \text{ decibels}$$

Where A_e = excess attenuation:

A_{e1} = attenuation due to molecular absorption.

A_{e2} = attenuation due to rigid barriers.

A_{e3} = attenuation due to dense woods.

A_{e4} = attenuation due to low vegetation.

We examined the transmission of human-related noises in three outdoor settings: (1) woods, (2) streamside in woods, and (3) meadow. In each of these settings different combinations of factors affecting noise attenuation may be operational. Table 2 presents a matrix showing which noise-attenuating factors are associated with each of these outdoor settings.

Table 2.--*Presence of factors affecting noise attenuation in three outdoor settings*

Outdoor setting	Molecular absorption	Dense woods	Rigid barrier	Low ground cover
Woods	+	+	±	±
Streamside	+	+	—	—
Meadow	+	—	±	+

NOTE: + = factor present, ± = factor possibly present, — = factor probably not present.

Background Noise

The final factor which influences how far noise will travel outdoors is the background noise level. In this section we discuss the effect of "natural" background noise on the distance an intrusive, human-related noise will travel. We also present the noise levels we measured in the three outdoor settings mentioned above.

The louder the ever-present background noise level, the closer a noise source can be to a receiver and still remain indistinguishable. Harrison (1974b, p. 16) suggests that for an intrusive noise to be "completely muffled, its sound level should be. . . reduced to about 15 dBA below the prevailing background noise."

In each of the three outdoor settings which we studied, there was an ever-present background noise level. In the woods, noises included the rustling of leaves and needles and the creaking of tree trunks. Under low wind conditions (3 to 5 mi/h), the background noise level in the woods (fig. 3) was about 35 dBA.[13/]

[13/] For comparison, at midafternoon, mean intensity of background noise in an urban area has been determined to be about 62 dBA, 75 dBA, and 80 dBA for residential, commercial, and industrial sites, respectively. Benjamin Etan Fanta. 1972. Noise generation and transmission in Jasper National Park. Unpublished M.S. thesis, University of Alberta, Edmonton.

Figure 3.--Under low wind conditions, background noise level in a mature coniferous forest such as this is about 35 dBA.

At streamside the turbulence of the water determines the background noise level (fig. 4). Opposite a small rapids on a 10- to 20-foot-wide stream, background noise level was about 45 dBA 3 feet from the bank.

In an open meadow (fig. 5), the rustling of grasses and brush stirred by the wind together with the distant sound of tree movement contributes to a background noise level of about 30 dBA under low wind (3 to 5 mi/h) conditions.

Figure 4.--Background noise level about 3 feet from the bank of a stream similar to this is about 45 dBA.

Figure 5.--In a meadow such as the one pictured here, background noise level is about 30 dBA under low wind conditions.

Campsite Spacing Guidelines

The spacing guidelines are based only on the physical properties of intrusive and background noises and applicable environmental factors which might attenuate the noise. In some cases, the suggested spacing guidelines may be difficult or impossible to achieve. Where practical considerations require closer spacing, the recreation manager should be especially sensitive to the following:

1. Types of human-related noises to be screened. What are the intensity and perceived intrusiveness of the "people" noises most likely to be encountered in the campsite area?

2. Background noise level. How can camps be located to take maximum advantage of areas with high intensity "natural" noise levels?

3. Attenuating factors such as barriers and foliage. What spatial arrangement of camps best uses the noise-attenuating properties of the environment?

4. Environmental features which can block visibility of noise sources. How can these features be exploited to provide the optimum degree of psychological insulation between campsites?

Insulation from noise is only one consideration in campsite location, but it is an important dimension of the wilderness and backcountry experience. Other factors which influence camp location are amount of level ground, distance from firewood and potable water, dryness of site, and visibility of lake or stream (Brown and Schomaker 1974). Obviously there are cases where the visitor may trade insulation from noise for a view or some other desired campsite feature.

Most noises which are related to human presence in wilderness settings occur in or around a campsite or on a trail. Several noises, such as safety whistles used to signal party members or a gunshot fired while a person is hunting, may be emitted from almost any location accessible to people. We considered only normal campsite and trail noises (singing, harmonica playing, pounding tent stakes, clattering pans, chopping wood, etc.) in determining guidelines for minimum campsite spacing. Since motorized vehicles are prohibited in many backcountry areas, we did not consider trailbikes in our spacing requirements. In areas where motorized vehicles are permitted, they would be expected to have substantial auditory impact. Harrison (1974a) has found that in a forest a motorcycle becomes just audible at distances ranging from 1,400 feet to 3,900 feet from the receiver, depending on the size and type of cycle.

Outdoor settings with differing background noise levels and combinations of attenuating factors require different spacing requirements to achieve the same level of insulation from intrusive noises. For example, campsites in a meadow must be more widely separated than camps in the woods to attain the same degree of insulation from noise.

Also, spacing requirements for similar outdoor settings (woods, streamside, and meadow) will vary according to the situation being considered. In the following we describe a procedure to determine campsite spacing to achieve noise standards that have been proposed for these situations--pristine, primitive, and portal.[14/]

[14/] Willis E. Ragland. 1973. Guides for proportioning wilderness into three situation classes. Unpublished manuscript on file at Mount Baker-Snoqualmie National Forest, 1601 Second Ave. Bldg., Seattle, Washington 98101.

PROCEDURE TO DETERMINE NECESSARY SPACING

1. Establish the standard of insulation. This step requires a determination of the loudest intrusive noise for which adequate spacing must be provided to render that noise indistinguishable from the background noise. For example, the noise might be pots rattling or children yelling--or in a more accessible setting it might be normal conversation.

2. Determine the threshold level of the setting. The threshold level is that sound level to which the noise must be reduced before it is muffled by background noise. This was determined to be 15 dBA less than the background sound level of the setting. For example, in a streamside setting with a background noise level of about 45 dBA, a threshold level of 30 dBA must be achieved before the intrusive noise is effectively masked by the sound of the stream.

3. Calculate spacing requirements appropriate for each setting. This final step involves calculating the distance the noise would travel, subject to the effect of available attenuating factors, before it reaches the threshold level for the setting.

PROPOSED NOISE CRITERIA AND SPACING STANDARDS FOR PRISTINE, PRIMITIVE, AND PORTAL SITUATIONS

Spacing requirements to achieve proposed levels of sound insulation for pristine, primitive, and portal situations are discussed below and summarized in table 1. For each zone different spacing requirements are given for meadow, woods, and streamside camp locations.

Pristine Situation

Here the proposed objective is to locate sites so that all "people" noises are inaudible between camps. This relatively stringent requirement assumes a desire by visitors to the pristine areas for a natural environment providing both solitude and isolation. Therefore, campsites should be located so that even a high intensity noise, such as human yelling (78 dBA), is not audible between camps.

In the woods, when a hill or rise 15 feet high is between the noise source and the campsite, at a distance of about 25 feet from the noise source the minimum spacing is reduced to about 1,600 feet. Next to a stream, the background noise level is higher, thus providing more "masking." If woods are between the noise source and the streamside campsite, 3,200-foot spacing is required before a yell will be inaudible.

In a meadow, noise source and receiver must be spaced farther apart than in a woods environment. Under certain conditions (downwind, high humidity, etc.), a yell will travel nearly 4 miles (20,000 feet) over level

ground before it falls below the threshold noise level. Of course, such a large open space is seldom found; in the wilderness setting, most large meadow environments occur in alpine areas where the distance sound will carry is reduced by ridges and hills. If two camps are located at an equal distance from a ridge which is at least 100 feet higher than each camp, minimum spacing is about 640 feet.

Primitive Situation

In the primitive zone, visitors' expectations of solitude and isolation are somewhat less than in the pristine situation and there are likely to be more people. The noise level proposed for this zone is 60 dBA--the level of intensity for four persons singing.

In the woods, minimum spacing of about 1,450 feet is required before the noise of four persons singing is masked by the background noise. When a hill or other rigid barrier 15 feet high is between noise source and receiver at a distance of 25 feet from the source, minimum spacing is reduced to about 400 feet.

In a streamside campsite in the woods, the intensity of singing must be reduced to 30 dBA before it is masked by the background noise. This requires a minimum spacing of 600 feet between campsites.

In a level meadow environment, singing can be heard at a distance of about 4,200 feet from the receiver. With a 100-foot-tall barrier (a ridge or hill) between source and receiver, minimum spacing is reduced to about 950 feet when camps are located at equal distance from ridgetop.

Portal Situation

In the portal situation, the more accessible and intensly used portions of the backcountry or wilderness, visitors' expectations for solitude are assumed to be less than in the more isolated ones. Thus, the standard for isolation in the portal areas is to locate camps so that the noise of 48 dBA--four people carrying on a conversation--is inaudible between sites.

Conversation becomes inaudible in a woods environment at about 500 feet. When a 15-foot-high barrier is interposed between source and receiver of the noise, spacing of campsites is reduced to about 200 feet.

At streamside campsites in the woods, a minimum spacing of 250 feet is required between noise source and receiver. Conversation is inaudible in a meadow environment over level ground at about 1,950 feet. When a ridge 100 feet high is between the noise source and receiver, spacing of about 250 feet with each camp an equal distance from the ridgetop is necessary to reduce conversation to the threshold noise level.

Campsite Location Guidelines

The foregoing data, literature review, and discussion suggest several guidelines for planning campsite locations where planning is possible, or relocating undesirable campsites:

1. Locate campsites laterally along streams. Managers should take advantage of the masking effect of the background noises of turbulent water and locate camps laterally along streams. Sites should be located as near the bank as is ecologically sound and opposite areas of swift water. Adjacent sites should be separated by dense vegetation and relief.

2. Do not locate campsites near lakeshores. The acoustic properties of the still air above a lake surface do little to decrease the intensity of noise traveling across the lake. Under certain climatic conditions a low conversation (about 45 dBA) is audible at a distance of over 1,000 feet.

Campsites should not be located directly across the lake from another but along the shore on the same side to take advantage of screening vegetation and terrain.

The small size of most high-country lakes precludes more than one camp near the lakeshore if even minimal auditory isolation is desired. If possible, locate sites along an uneven shoreline with vegetation and relief between them. It is also helpful to set sites back into the woods, taking advantage of noise attenuation by dense vegetation and the psychological isolation afforded by visual screening.

3. Meadows are unsuitable location for multiple campsites. The noise attenuation effect of low vegetation is minimal. In addition, except at very great distances, visual impact of other parties accentuates auditory impacts. Locations of multiple camps in a meadow setting should be considered only where they can be separated by ridges or hills or where they can be set back in the timber surrounding the meadow.

4. Take maximum advantage of environmental features which lessen noise. The judicious use of topography in locating campsites greatly lessens transmission of noise between camps. Whenever possible, separate camps by vegetation and rigid barriers--rises, ridges, rocks, or hills--to reduce both noise transmission and visual perception of the human origin of noise.

5. Take advantage of areas with a high background noise level. The turbulence of a rushing stream, a waterfall, the rustling of brush and tree leaves stirred by the wind, the sound of waves at shore areas all raise the natural background noise level which can help screen out human-related noises. Locating camps in areas with high background noise will allow closer campsite spacing while maintaining auditory isolation.

Conclusions

In this study we reviewed some basic principles of sound transmission and presented empirical findings of the sound levels of various human-related noises. Based on this information we developed guidelines for campsite spacing and location in wilderness and backcountry settings. The guidelines recognize the desirability of different sound standards fitting user expectations in different roadless area situations--pristine, primitive, and portal. In hard-to-reach, interior portions of a roadless area (pristine) situation visitor expectations for solitude are greatest. Here more stringent sound standards are justified, and camps must be spaced more widely apart than is necessary in intermediate (primitive) or peripheral (portal) situations where visitors expect less isolation.

The distances we suggest for campsite spacing are offered only as rough guidelines. They might also be used as diagnostic criteria with which to appraise the experience at currently established sites from a noise-isolation standpoint. It is recognized that other factors are also important to the users' camping experience. Among these factors are availability of potable water, firewood, and dry and level ground.

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Robert Fogel

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
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ABSTRACT

Insects that feed on fungi are primary dispersal agents for many beneficial and pathogenic species. Nearly 300 references on the subject, published since the mid-19th century are listed in this bibliography.

Keywords: Bibliography, insect vectors, mycophagy, spores.

ABOUT THE AUTHOR

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For well over a century, certain insects have been known to feed on fungal fruiting bodies. Spore-eating insects have been presumed to be vectors of the fungi eaten. Only recently, however, have spores been demonstrated to remain viable after passage through an insect's digestive tract (Leach et al. 1934, Nuorteva and Laine 1972). These works have reawakened interest in the role of insect mycophagy in dissemination of pathogenic, mycorrhizal, and other fungi.

References in this bibliography are intended to provide an entry into the insect mycophagy literature. For brevity, most papers cited by earlier reviewers are not listed individually in this bibliography; i.e., papers cited by Hingley (1971), Benick (1952), Graham (1967), Weber (1972b), and Weiss (1921). The few references that I could not personally verify are marked with an asterisk and are cited as found in secondary sources.

The most frequently reported insect mycophagists are either Diptera, mainly Mycetophilidae or Phoridae, and Coleoptera, separable into bark beetles and other beetles. Agarics and "bracket" fungi (Polyporaceae) encompass most of the commonly reported substrates.

Most literature records insects extracted or reared from fungal sporocarps rather than observations of actual feeding on fungi. Complete food chains are thereby concealed, since some insects in sporocarps may be predators or casual visitors. However, such insects can also serve as carriers of spores. Food consumption rates, chemical composition, species numbers, models of food webs, etc., have rarely been reported.

The bibliographic search and compilation were supported in part by National Science Foundation Grant GB-36810X under the Coniferous Forest Biome, U.S. International Biological Program.

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SILVICULTURAL USE of Herbicides in Pacific Northwest Forests

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By H. Gratkowski

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE

Abstract

After a brief description of silvicultural problems, the author tells how to prescribe herbicidal sprays for aerial application in Pacific Northwest forests. The publication offers a detailed discussion of the five basic considerations: (1) selection of the best herbicide or herbicides, (2) amount of herbicide to be applied per acre, (3) carriers, (4) volume of spray per acre, and (5) seasons for application of aerial sprays.

Appendixes provide standard treatments for many common silvicultural problems in site preparation and to release young conifers from shrub and weed tree competition. Also included is a glossary of agricultural chemical terms and a list of abbreviations used in brush control literature.

This is a working manual for silviculturists based upon more than 20 years research and experience of Federal, State, and industrial foresters. It provides much information not generally available in the literature and tells how to use this knowledge in Pacific Northwest silviculture. Although designed primarily for the Pacific Northwest, the basic information should be useful in culture of coniferous forests far outside this region.

Keywords: Herbicide preparations, silvicultural control, management (forest).

Mention of product by name does not imply endorsement by U.S. Department of Agriculture of any product to the exclusion of others which may be suitable.

ABBREVIATIONS OF TERMS USED IN WEED CONTROL LITERATURE

Abbreviation	*Definition*
A	acre(s)
ae	acid equivalent
aehg	acid equivalent per 100 gallons
ai	active ingredient
aihg	active ingredient per 100 gallons
cfs	cubic feet per second
diam	diameter
fpm	feet per minute
ft	foot or feet
g	gram(s)
gal	gallon(s)
gpa	gallons per acre
gpm	gallons per minute
ht	height
in	inch(es)
l	liter(s)
lb	pound(s)
mg	milligram(s)
μm	micrometer (formerly micron, one one-thousandth of a millimeter)
min	minute(s)
ml	milliliter(s)
mm	millimeter(s)
mph	miles per hour
oz	ounce(s)
ppmv	parts per million by volume
ppmw	parts per million by weight
psi	pounds per square inch
pt	pint(s)
qt	quart(s)
rpm	revolutions per minute
sp gr	specific gravity
T	ton(s)
tech	technical
temp	temperature
vmd	median diameter of droplets in spray
wt	weight
w/v	weight per volume. Do not use this abbreviation. Instead give specific units (examples: g/l or lb/gal).

Contents

Introduction

The Pacific Northwest contains a wide range of habitats that are reflected in the many different forest types on commercial forest lands. Dense Sitka spruce-western hemlock and Douglas-fir forests are found in the warm, rainy habitats along the coast; but Douglas-fir is predominant throughout most of the Coast Ranges and on the west slope of the Cascade Range. True fir and mountain hemlock forests occupy a limited area along the crest of the Cascade Range, and ponderosa pine and lodgepole pine are most abundant in the dry intermountain region. Mixed conifer types containing Douglas-fir, ponderosa pine, sugar pine, incense cedar, white fir, and Shasta red fir are prevalent in southwestern Oregon.

Brushfields are equally diverse. Broad-sclerophyll forests of tanoak, golden chinkapin, and Pacific madrone with an understory of evergreen shrubs are common in the wetter western end of the Siskiyou Mountains (fig. 1); while a chaparral of evergreen brush species occupies drier sites in the same area and in the relatively arid eastern end of the Siskiyou Mountains. Mixed evergreen and deciduous brushfields containing a high percentage of evergreen shrubs occupy large areas devastated by forest fires in the southern end of the Cascade Range. Northward in both the Coast and Cascade Ranges, deciduous brush species and weed trees increase in abundance in shrub communities.

To safely achieve silvicultural objectives, foresters must select herbicidal treatments keyed to these variations in plant communities and environmental conditions. Although use of herbicides is complicated, research and experience during the past 20 years have shown that only a few herbicides are useful in Pacific Northwest silviculture. With modest effort, foresters can readily learn to consider the factors involved, prescribe treatments, and use these few herbicides safely and effectively.

Safety and economy demand that herbicidal chemicals be used as sparingly and infrequently as possible to accomplish our silvicultural objectives. Effective use requires that we apply minimal amounts of herbicides at the proper time of the year to obtain the maximum degree of control on undesirable species without damaging desirable tree species, wildlife browse, or esthetically desirable shrub species.

These objectives are best accomplished by early recognition and treatment of small shrubs and weed trees on burns and cuttings where brush problems threaten to develop. Better control of undesirable species can be accomplished with less herbicide, fewer treatments, and reduced contamination of the forest environment. Early recognition and treatment will also increase survival and growth rates of young conifers.

Figure 1.—This nonstocked brushfield of evergreen shrubs and weed trees occupied thousands of acres after fire swept the area 36 years ago.

Silvicultural Objectives

Two major objectives in application of herbicides on forest land are to release young conifers from brush and weed tree competition and to prepare sites for reforestation or interplanting with additional conifers.

The silvicultural objective in aerial spraying to release young conifers is not necessarily to kill all competitive vegetation, but to increase the amount of light reaching young conifers in the understory and decrease brush competition for soil moisture and nutrients. We need only obtain a high percentage of defoliation, a fair amount of topkill, and a minimum of resprouting. In fact, complete topkill may stimulate development of basal sprouts on many weed species and result in more rapid recovery and greater competition than if some of the original crown remains alive (fig. 2). Given 3 to 5 years of improved light and moisture, young conifers on most sites will outgrow the herbicide-damaged brush and be permanently released. Release spraying allows application of minimal amounts of herbicides,but requires careful choice of selective herbicides, carriers, and seasons of application.

For site preparation, much more complete control is needed. A high percentage of competitive woody vegetation must be killed, and there must be a minimum of resprouting. On areas where no conifers are present, site preparation treatments allow use of broad-spectrum herbicides or higher rates of the selective herbicides

used in release spraying. On nonstocked sites, herbicides are usually applied during the growing season in late spring, when plants are most susceptible to herbicides. Oil-in-water emulsion carriers are frequently used to obtain the greatest degree of shrub and weed tree control.

Site preparation may also call for saving scattered existing conifers on a site while controlling shrubs and weed trees enough to allow interplanting, survival, and growth of additional trees on the site. For such areas, treatments require more care. More selective herbicides such as low volatile esters of 2,4-D and/or 2,4,5-T are most frequently chosen for application. These herbicides are applied at minimal rates in carefully selected carriers during seasons when shrub and weed tree competition can be sufficiently reduced to allow survival and growth of newly planted small trees without damaging trees already present amid the shrubs. Budbreak, late foliar, or late summer applications of herbicides are usually preferred for such areas. The prime objectives are to increase light and available soil moisture. . . especially to the new trees.

Mechanical eradication is possible on some sites, but this method is expensive and often damages trees hidden within the shrubs. With either method, subsequent application of herbicides is usually required to kill new brush seedlings, retard growth of resprouting shrubs, and insure survival and dominance of the interplanted trees on most sites (fig. 3).

Figure 2.—Flagging—development of a limited amount of new foliage—along main stems and branches reduces production of basal sprouts on many shrubs and weed trees.

Figure 3.—Six years after mechanical eradication, growth of resprouting shrubs and weed trees threatened survival of young conifers planted on this site in the Cascade Range.

Herbicides are also used to kill and desiccate shrubs and weed trees on nonstocked sites, to prepare the areas for reforestation. Contact herbicides such as dinitro (4,6-dinitro-o-sec-butylphenol) and paraquat (1,1'-dimethyl-4,4'-bipyridium ion) in water carriers are sometimes applied as defoliants in late summer to prepare brush for burning. As contact herbicides, however, their prime effect is a rapid killing and drying of foliage. They produce little or no stem kill; therefore, areas to be burned should receive their major preburn treatment with a phenoxy herbicide, picloram, or other slower acting, systemic herbicide. The contact herbicide should only be applied a week or two before burning to kill any green foliage, add to the dry fuel, and allow penetration of sunlight to further desiccate litter and other fuel on the soil surface.

Factors in Herbicidal Treatments

Prescribing herbicidal treatments in silviculture is not as complicated, difficult, or mysterious as it may seem. It is a relatively simple process in which only five items must be specified. These are: (1) herbicide or herbicides to be used, (2) rate or amount of herbicide to be applied per acre, (3) carrier, (4) volume of spray per acre, and (5) season of application.

Other contract specifications are merely refinements of these basic considerations. Special application equipment and drift control agents may be required, especially during aerial spraying (fig. 4). These allow accurate placement of aerial sprays near ownership lines or insure that unsprayed buffer strips will be left along streams and waterways, around habitats of rare or endangered species, to preserve wildlife winter range, or to protect other ecologically sensitive areas. Forest practice laws and several publications spell out safety requirements for transport, mixing, and aerial application of herbicides in the field (Brazelton 1971, Gratkowski and Stewart 1973, Gratkowski 1974).

Figure 4.—Helicopter applying a foamed spray to reduce herbicidal drift.

Many techniques and restrictions have already been imposed by foresters to control drift and other spray losses, preserve buffer strips, and eliminate damage to other ownerships and ecologically sensitive areas. Volatilization is minimized by use of low volatile esters and by spraying only when air temperature is below 75°F and relative humidity above 50 percent. To minimize drift, aerial spraying is stopped when windspeed exceeds 6 miles per hour, when air temperatures rise above 70°F, producing convection currents that rise from heated slopes and prevent the spray from falling to the brush cover, or when other weather conditions are not suitable. Flying speed is limited to a maximum of 40 to 50 miles per hour, and flying height is generally 20 to 45 feet above the vegetation. With conventional spray booms, drift is also controlled by use of nozzles with an orifice size that will produce the largest droplets compatible with adequate coverage and desired effect upon the vegetation. Larger and heavier droplets fall more directly, strike the vegetation more quickly, and drift less than small droplets or mists.

In addition, invert emulsions, spray thickeners, foamed sprays, and special aerial spray equipment have been developed to minimize volatilization and insure more accurate application of aerial sprays. Such materials and equipment are already being used by a large percentage of silviculturists during aerial application of herbicides.

Herbicides and Formulations

For many years, a great number of different herbicidal formulations were used in forestry. Many were not specifically designated for silvicultural use but were applied as an extension of their registration for agricultural use. In recent years, however, Federal and State regulations have become more strict and specific. They now require that only herbicides labeled and registered for forest use be applied on forest lands. Questions concerning the registration of a particular formulation should be directed to the appropriate State Department of Agriculture, the Oregon State Board of Forestry, the Washington State Department of Natural Resources, or the Environmental Protection Agency which is now responsible for Federal registration of all pesticides. Many States also have laws that provide special regulations for specific herbicides and areas where they may be used. Federal foresters applying herbicides on forest lands can consult their appropriate regional pesticide coordinator to secure necessary approval for treatments.

Data on physical characteristics of herbicides are adequately covered in the Oregon Weed Control Handbook, the Washington Weed Control Handbook, the Washington Pest Control Handbook, and the Herbicide Handbook of the Weed Science Society of America. It would be redundant to repeat that information.

Neither will this publication attempt to discuss technical aspects of herbicidal formulation. Instead, it will offer some information that is not generally available in the literature. And since aerial spraying is most economical and most frequently used in applying herbicides on forest land, this publication will stress choice of treatments for aerial application (fig. 5).

Figure 5.—To reduce drift and evaporation and insure accurate application of herbicidal sprays, helicopters fly at minimum safe flying height over brushfields.

HERBICIDES

Many chemicals have herbicidal activity, but the way they are used and their effectiveness depend upon the physical characteristics of the chemical and the way it is formulated. Kirch (1967) stated that the two main objectives in formulating herbicides are to put the chemical in the best possible form for use in the field and to improve the herbicide's performance by increasing its penetration, translocation, and accumulation within the plants to be controlled. Most herbicidal compounds are initially produced as white crystalline acids or powders insoluble in water. In this form, they would be difficult to apply and relatively ineffective on woody plants (Kirch 1961). Therefore, the basic herbicidal compounds are chemically modified to increase their biological activity, allow small amounts to be spread over large areas, and ease handling and mixing in the field.

Research and experience over the past 20 years have shown that only a limited number of herbicides are useful in silviculture. Common and chemical names of these compounds are listed below. The phenoxy (or hormone) herbicides—especially low volatile esters of 2,4-D and 2,4,5-T—are especially important in silviculture. These chemicals are used on approximately 75 percent of the acreage treated annually, and they are the most important chemicals for controlling woody plants. The next most abundantly used chemical in Pacific Northwest forests is atrazine, followed by picloram, silvex, and amitrole-T.

Common name	*Chemical name*
2,4-D	(2,4-dichlorophenoxy) acetic acid
2,4,5-T	(2,4,5-trichlorophenoxy) acetic acid
amitrole-T	3-amino-*s*-triazole plus ammonium thiocyanate
silvex (2,4,5-TP)	2-(2,4,5-trichlorophenoxy) propionic acid
dichlorprop (2,4-DP)	2-(2,4-dichlorophenoxy) propionic acid
picloram	4-amino-3,5,6-trichloropicolinic acid
dicamba	3,6-dichloro-*o*-anisic acid
cacodylic acid	hydroxydimethylarsinic acid
atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine
dalapon	2,2-dichloropropionic acid

The first eight herbicides are primarily used for woody plant control, but they are also effective on broadleaf weeds. Although atrazine and dalapon are mainly used for grass control, some broadleaf weeds may also be killed with these chemicals.

With a proper choice of rate, carrier, and season of application, 2,4-D, 2,4,5-T, silvex, atrazine, dalapon, and amitrole-T can all be used to release young conifers from competitive vegetation. All of these plus picloram and dicamba can also be used for site preparation. Picloram and dicamba, however, can't be used to release conifers; they are not selective and damage young trees.

In selecting a herbicidal treatment for a particular site, the choice is usually dictated by two to four species that are predominant in the brushfield. The actual choice among suitable chemicals is based upon silvicultural objectives to be achieved. Many publications are available to guide foresters in choosing the most effective herbicides for our major brush species and conifers in Pacific Northwest forests (see literature cited on pages 26 to 28). These recommendations are based upon intensive research by Federal, State, and industrial organizations and experience of silviculturists over the past 25 years. Results are presented in numerous publications that offer information like that shown in table 1.

For example, the data in table 1 show that both 2,4-D and 2,4,5-T are almost equally effective on manzanitas . . . with a slight edge in favor of 2,4-D. And since 2,4-D is only half as expensive as 2,4,5-T, it is most economical to use 2,4-D to control manzanita.

But mountain whitethorn is more susceptible to 2,4,5-T. Both 2,4-D and 2,4,5-T completely killed the tops of mountain whitethorn, but 2,4-D only killed 5 percent of the plants while 2,4,5-T killed 20 percent. Obviously, 2,4,5-T is the best herbicide to control mountain whitethorn.

These differences in effectiveness become even more pronounced with repeated applications of foliar sprays applied on shrubs during the period of active growth (tables 2 and 3). On mountain whitethorn, for example, three applications of 2,4-D and 2,4,5-T gave quite different results. Shrub kill with 2,4-D was only 5 percent after the first spray, 20 percent after a second treatment, and only 55 percent after the third spray. With 2,4,5-T, however, initial kill was 20 percent, then went to 65 percent, and then to 90 percent. In contrast, scrub tanoak is equally susceptible to both 2,4-D and 2,4,5-T.

Table 1.--*Degree of control achieved with foliar applications of 2,4,5-T and other herbicides in Pacific Northwest forests*[1/]

Species	Herbicide				
	2,4-D	2,4,5-T	Silvex	Dichlorprop	Amitrole-T
	- - - - Percent topkill/percent plants dead - - - -				
Alder, red	92/90	100/100	50/50	70/70	--
Ceanothus, deerbrush	100/90	100/85	--	--	--
Ceanothus, snowbrush	96/20	100/30	100/0	99/50	--
Ceanothus, varnishleaf	74/45	93/65	88/60	60/30	--
Chinkapin, golden	38/0	61/0	58/0	51/0	--
Chinkapin, golden-evergreen	58/0	67/0	44/0	62/0	--
Chinkapin, Sierra evergreen	98/0	100/0	--	--	--
Hazel, California	--	100/40	98/0	98/0	--
Manzanita, greenleaf	95/15	84/0	--	--	--
Manzanita, hairy	100/100	95/90	--	--	--
Manzanita, hoary	100/100	97/85	--	--	--
Manzanita, Howell	100/95	96/85	--	--	--
Maple, vine	--	100/80	100/90	46/30	--
Oak, canyon live	44/0	32/0	--	--	--
Salmonberry	--	100/50	100/20	100/40	74/70
Serviceberry, Saskatoon	50/0	68/0	--	--	--
Tanoak, scrub	40/0	43/0	--	--	--
Thimbleberry	--	100/10	100/10	100/0	--
Whitethorn, mountain	100/5	100/20	--	100/0	--

1/ Data from Gratkowski (1959) and Stewart (1974b).

Table 2.--*Cumulative percentage*[1] *of shrubs killed by repeated foliar sprays of herbicides on mature (1955) and resprouting (1957 and 1959) brush species in southwestern Oregon*[2]

Species and herbicide	Concentration	Carrier	1955	1957	1959
	Lb aehg[3]	- - Percentage of shrubs killed - -			
Hairy manzanita					
2,4-D	1	Water	100	(—)[4]	(—)[4]
2,4,5-T	1	Water	90	(—)[4]	(—)[4]
2,4,5-T	2	Water	100	(—)[4]	(—)[4]
Hoary manzanita					
2,4-D	1	Water	100	(—)[4]	(—)[4]
2,4,5-T	1	Water	85	(—)[4]	(—)[4]
2,4,5-T	2	Water	100	(—)[4]	(—)[4]
Howell manzanita					
2,4-D	2	Water	95	(—)[4]	(—)[4]
2,4-D	2	Emulsion	100	(—)[4]	(—)[4]
2,4,5-T	2	Water	85	(—)[4]	(—)[4]
Deerbrush ceanothus					
2,4-D	2	Water	90	(—)[4]	(—)[4]
2,4-D	2	Emulsion	80	(—)[4]	(—)[4]
2,4,5-T	2	Water	85	(—)[4]	(—)[4]
Snowbrush ceanothus					
2,4-D	2	Emulsion	20	65	(—)[4]
2,4,5-T	2	Emulsion	30	80	(—)[4]
2,4,5-T	4	Emulsion	40	95	(—)[4]
2,4,5-T + amitrole	2	Water	70	90	(—)[4]
Varnishleaf ceanothus					
2,4-D	2	Emulsion	45	60	(—)[4]
2,4,5-T	2	Emulsion	65	95	(—)[4]
2,4,5-T	4	Emulsion	85	100	(—)[4]
Mountain whitethorn					
2,4-D	2	Water	5	20	55
2,4,5-T	2	Water	20	65	90
Greenleaf manzanita					
2,4-D	2	Water	15	45	90
2,4-D	2	Emulsion	20	30	80
Golden chinkapin					
2,4-D	2	Emulsion	0	15	25
2,4,5-T	2	Emulsion	0	25	55
Amitrole	4	Water	0	20	60
2,4-DP + amitrole	2	Water	10	30	50
Golden evergreenchinkapin					
2,4-D	2	Emulsion	0	20	30
2,4,5-T	2	Emulsion	0	15	55
Amitrole	4	Water	0	40	60
Scrub tanoak					
2,4-D	2	Emulsion	0	35	55
2,4,5-T	2	Emulsion	0	20	60
Serviceberry					
2,4-D	1/2	Water	0	40	50
2,4-D	2	Water	0	40	60
Canyon live oak					
2,4-D	2	Emulsion	0	0	5
2,4-D	4	Emulsion	0	0	5

[1] 1955 and 1957 sprays were rated just before the next respray was applied. The 1959 treatments were rated in autumn, 1960.

[2] From Gratkowski (1968).

[3] Pounds acid equivalent per 100 gallons. For amitrole, read aihg (active ingredient per 100 gallons).

[4] No respray.

Table 3.--*Cumulative percentage of shrubs killed by repeated foliar sprays on mature (1970) and resprouting (1972) brush species in the Oregon Coast Ranges* [1]

Species and herbicide	Concen-tration	Carrier	Early foliar spray, 1970[2]	Early foliar respray, 1972[2]
	Lb aehg[3]	- - Percentage of shrubs killed - -		
Salmonberry				
2,4,5-T	3	Emulsion	50	90
Amitrole-T	1	Water	70	70
	3	Water	80	80
Picloram	1	Water	70	90
Western thimbleberry				
2,4,5-T	3	Emulsion	50	90
Amitrole-T	1	Water	10	20
	3	Water	20	50
Picloram	1	Water	70	100
Vine maple				
2,4,5-T	1	Water	0	20
	3	Water	40	80
Silvex	1	Water	10	30
	3	Water	30	50
Picloram	1	Water	40	80
California hazel				
2,4,5-T	1	Water	20	80
	3	Water	60	100
Silvex	1	Water	40	70
	3	Water	10	70
Picloram	1	Water	80	100

[1] From Stewart (1974c).

[2] When 3/4 of the leaves were fully developed.

[3] Pounds acid equivalent per 100 gallons. For amitrole, read aihg (active ingredient per 100 gallons).

Tables such as these provide very helpful information in selecting the most effective herbicide or herbicides to control individual species or combinations of brush species.

Application of the most effective herbicide will allow use of minimal amounts of chemical per acre, generally reduce costs, and minimize contamination of the forest environment. In release sprays, however, choice of herbicide may necessarily be modified in order to minimize damage to young conifers.

Phenoxy Herbicides

The phenoxy herbicides, especially 2,4-D and 2,4,5-T, are by far the most useful herbicides in silviculture. A major advantage of these herbicides is the great range of selective activity that can be obtained by changing carriers and by varying rates and seasons of application (Gratkowski 1961b, Sutton 1967). None of the other herbicides allow such selective control. This versatility makes 2,4-D and 2,4,5-T invaluable in silviculture.

Other phenoxy herbicides such as silvex and dichlorprop control certain species but are not as effective as 2,4-D and 2,4,5-T on the broad spectrum of native shrubs and weed trees found on Pacific Northwest forest lands.

2,4-D and 2,4,5-T are often combined in a "brushkiller" mixture. Such mixtures are especially useful if a half dozen or more species are abundant in the plant communities to be treated (fig. 6). They are less useful, however, if only three or four species are predominant and most are susceptible to one of the herbicides while only a minor component of the shrub cover is susceptible to the other. Since most commercial brushkiller mixtures usually contain a 1:1 mixture of 2,4-D and 2,4,5-T, they will not provide the maximum degree of control on the more abundant species in such plant communities unless an excessive amount of herbicide is used. However, at least one company produces a series of brushkiller mixtures in which the proportions of 2,4-D and 2,4,5-T are varied. If species composition varies considerably from area to area, it is wise to purchase such commercial formulations to meet your need. If they are not available, however, you can prepare your own brushkiller mixture in the field. It should contain a higher percentage of the herbicide that will be most effective on the more abundant shrub species in the brushfield. Such mixtures can be prepared in the nurse tank truck just before application.

However, in preparing brushkiller mixtures in the field, similar esters of both herbicides should be obtained from the same manufacturer to assure compatibility of the two formulations in the spray mixture. Products from two different manufacturers may be formulated in different systems of oils, emulsifiers, wetting agents, and penetrants that may not be compatible. This is not as important when using oil carriers as when using water or oil-in-water emulsion carriers. Since esters are soluble in oil and are formulated in oil, all can be dissolved in diesel oil or in No. 2 fuel oil carriers for budbreak sprays.

Also, in preparing field-mixed brushkiller mixtures for use in water carriers or in oil-in-water emulsions, a formulation designated only for oil carriers should not be mixed with another designated for water carriers or for oil-in-water emulsions. The resultant mixture may not contain enough emulsifier to produce a stable emulsion.

In such cases, the spray mixture may break down and the oil-and-herbicide solution will rise to the surface of the water phase in the nurse tank. Even with compatible formulations, a continual, mild agitation of emulsion and water sprays in the nurse tank is advisable to prevent separation.

Figure 6.—Two aerial applications of phenoxy herbicides in emulsion carriers released suppressed Douglas-firs from 30- to 40-foot-tall evergreen weed trees and a dense brush understory.

Amitrole-T

Amitrole-T has been most frequently used to control salmonberry, and it may still be the most effective chemical for controlling salmonberry during early spring. However, there is a change in susceptibility of salmonberry as the season progresses. By late spring, 2,4,5-T is at least as effective as amitrole-T. By midsummer, 2,4,5-T in an oil-in-water emulsion carrier is far more effective than amitrole-T on salmonberry and also provides a fair degree of control on thimbleberry as well (Gratkowski 1971, Stewart 1974b). Since thimbleberry is commonly associated with salmonberry and frequently takes over sites where salmonberry has been controlled, use of 2,4,5-T rather than amitrole-T is recommended for release spraying or site preparation where salmonberry and western thimbleberry are intermixed and abundant in the brush community. Both species are controlled with one application of 2,4,5-T. Properly used, 2,4,5-T is also less damaging to conifers.

Amitrole-T is no longer registered for use on pastures and other land subject to grazing of domestic animals.

Picloram

Picloram is a nonselective herbicide. It seriously damages young conifers when applied as a broadcast aerial spray and is not suitable for releasing conifers from brush competition. Combined with phenoxy herbicides, however, picloram is an

excellent chemical for site preparation. West of the crest of the Cascade Range, picloram does not appear to persist in damaging concentrations in the soil for unreasonably long periods, especially in soils with high organic matter content. Sites can be planted with Douglas-firs within 8 months to 1 year after application of up to 1 lb of picloram plus 4 lb ae of 2,4-D per acre (Finnis and Sund 1970). Stewart (1974b) is also evaluating aerial spray tests of picloram in combination with 2,4-D and 2,4,5-T for preburn desiccation of vegetation in site preparation. He reports that initial results indicate use of picloram may reduce resprouting of shrubs after burning.

Dicamba

Dicamba is another relatively nonselective herbicide that produced extensive defoliation and topkill of conifers in both late spring and early summer sprays (Stewart 1974b). Dicamba should not be used alone or in combination with phenoxy herbicides to release young conifers from brush competition. It is useful only for site preparation.

Cacodylic acid

Cacodylic acid has been used to some extent as a silvicide injected into trees during thinning and weeding operations. Care should be exercised to prevent dermal contact with this herbicide. Those using cacodylic acid should be provided protective clothing including rubber gloves.

Atrazine

Extensive testing and experience has shown that atrazine is by far the most effective herbicide for grass control in Pacific Northwest forests. Unfortunately, it is registered for use only on forest lands west of the crest of the Cascade Range. It cannot be used in eastern Oregon and Washington. Effective rates of application on the west side are 4 lb active ingredient per acre applied in a water carrier during February or March. Sufficient rain must fall after application to leach atrazine into the soil, where it can be absorbed through root systems of susceptible grass species. Atrazine provides very little control of broadleaf weeds, which often increase markedly in abundance and may reduce release achieved by grass control. Grass control achieved with atrazine is very pronounced during the first summer after application; regrowth begins with the onset of autumn rains.

Atrazine is sometimes combined with 2,4-D or 3 to 5 lb active ingredient of dalapon per acre in an attempt to control broadleaf weeds as well as grass. These mixtures have been used for some time to release young Douglas-firs from grass competition. In at least one area in southwestern Oregon, however, a combination of atrazine and dalapon resulted in complete defoliation of well-established ponderosa pines 8 to 15 feet tall. Such damage is extremely undesirable and indicates a synergistic effect of these two chemicals which increases their activity and effect upon conifers. The author does not consider use of atrazine-dalapon mixtures advisable on ponderosa pines.

Dalapon

Dalapon is the only herbicide registered for grass control on forest lands east of the Cascade Range in Washington and Oregon. In preplanting applications, dalapon must be applied at least 2 weeks before planting conifers. However, results of tests run by Stewart and Beebe (1974) on the Wenatchee National Forest indicate that 5 lb of dalapon per acre will provide adequate grass control without damaging ponderosa pine seedlings planted immediately after spraying.

FORMULATIONS

Most silvicultural herbicides are formulated as esters, emulsifiable acids, water- or oil-soluble amines, or wettable powders. These basic formulations may be further modified for application as liquid sprays in oil, water, oil-in-water emulsions, as invert emulsions or thickened sprays, or in dry form as granules or pellets (fig. 7).

Figure 7.—Granular herbicides are especially useful for site preparation in multistoried communities of shrubs and weed trees. Red alder in this stand, however, is near merchantable size and should not be killed but grown and harvested later in type conversion.

Esters

Low volatile esters of the phenoxy herbicides 2,4-D and 2,4,5-T are by far the most widely used formulations on forest lands. These are liquid formulations with the esters dissolved in oil. They are easily transported and mixed in the field. In addition, they are readily absorbed into leaves and stems, are biologically active at very low rates, and a variety of formulations are available that provide stable spray mixtures in the several different carriers required for selective silvicultural use.

Esters are formed by the reaction of a parent acid such as 2,4-D with an alcohol and are generally named for the alcohol from which they are made (Kirch 1967). Only low volatile ester formulations should be used in forestry. These are formed from alcohols that have more than five carbon atoms in the chain such as propyleneglycolbutyl ethers, butoxy ethanol or isooctyl alcohols.[1] Foresters should remember, however, that even low volatile esters will begin to vaporize during application when air temperatures approach 90°F. Soil, bark, and leaf surfaces may reach this temperature when air temperature is considerably lower than 90°F. As a result, contract specifications usually require that aerial spraying must cease when air temperature exceeds 70°F.

Most esters, like the parent acids, are not soluble in water. In commercial formulations, therefore, esters are dissolved in oil with other additives to improve mixing, penetration, and biological activity in the field. In addition to the herbicide and oil, a good commercial formulation may contain filming or wetting agents, emulsion stabilizers, penetrants, solvents, coupling agents, and in some cases an antifreeze compound. Since esters are formulated in oil, they are soluble in and may be applied in oil carriers. If they are to be used in water or oil-in-water emulsions, however, the formulation must contain an emulsifier to form a stable emulsion in the mixing tank.

Amine and Metallic Salts

Water-soluble amines of phenoxy herbicides are probably the next most widely used formulations in forestry. Amine salts are formed by neutralizing the organic acid with an amine to form a salt. Water-soluble amines are especially useful in cut surface treatments, where the chemical is placed in direct contact with water- and nutrient-conducting elements of phloem and xylem. Since both food and nutrients move in aqueous solutions in phloem and xylem, water-soluble amine formulations are also readily dissolved and translocated with these materials throughout shrubs and weed trees. Water-soluble amines, however, are relatively ineffective as foliage sprays, except in the case of highly phytotoxic herbicides such as picloram.

Oil-soluble amines have been manufactured in an effort to provide relatively nonvolatile herbicides for foliage sprays. In theory, the amine in oil phase would pass through the cuticle into the leaf and then move in the water phase of the plant. Kirch (1967) indicated oil-soluble amines might equal low volatile esters in performance if applied at high volumes, but believed their main advantage is decreased volatility.

Initially, alkali metal salts were also manufactured using sodium, ammonium, potassium, magnesium, and other salts; but these have largely been discarded. Their greatest value was in broadleaf weed control, and they were of limited value in forestry.

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[1] Paul M. Ritty. Some aspects of the formulation of herbicides. Agricultural Chemicals Development, Dow Chemical Company, Midland, Michigan. 4 p, mimeo., 1960.

Emulsifiable Acids

Parent acids of the phenoxy herbicides can be solubilized in special formulations so that they may be applied in water carriers. These formulations are sometimes referred to as free acid formulations but evidently contain some low volatile esters as well. They are relatively low in volatility and have proved useful on some hard-to-kill perennial weeds and woody plants (Kirch 1967). However, low volatile ester formulations are far more useful in silviculture.

Powders

Some herbicides such as atrazine for grass control are manufactured as wettable powders by mixing the herbicide with an inert carrier. With wetting and dispersing agents added in the commercial formulations, powders can be mixed to form a fine suspension for application in water carriers. Such formulations are generally very low in volatility but most useful for herbicides to be leached into the soil and absorbed through root systems. Soil sterilants are frequently formulated as wettable powders.

Dalapon, another grass control chemical, is formulated as a water-soluble powder. Water-soluble powders are much easier formulations to mix and apply in the field.

Granules and Pellets

Granular or pelleted nonselective, soil-active herbicides are especially useful in multistoried stands of shrubs and weed trees, for they can be distributed by aircraft and drop through all levels of the plant canopy to the soil surface (fig. 7). There, they are leached into the soil by rainfall and absorbed by roots of all species. The chemicals must be effective on a broad range of woody plants and have no undesirable effects on water and soil or other life forms of the forest ecosystem. After killing undesirable plants, the herbicide also must degrade or decompose quickly to permit reforestation. Other plant life must be able to reoccupy the site in order to minimize soil erosion and maintain high quality of water from the treated area.

Rates of Application

Rates of application per acre depend upon silvicultural objectives, and some information has already been provided in the preceding sections. Proper rates are necessary not only to achieve a desired degree of brush control but to minimize damage to conifers in release spraying as well. Too high a rate in some seasons and on certain species may result in as little brush control as using too little herbicide.

Movement of phenoxy herbicides is associated with translocation of carbohydrates in plants. With deciduous species, especially during spring, high concentrations of herbicides may kill leaves too quickly, reduce absorption of the chemicals,

stop or reduce photosynthesis, minimize production and translocation of sugars, and thus reduce intake and movement of phenoxy herbicides into stems and roots. As a result, the degree of brush control achieved may be drastically reduced as well.

For release sprays, 20 years' experience has shown that phenoxy herbicides are most effective when applied at rates of 1 to 3 pounds acid equivalent (averaging 2 lb ae) per acre. In contrast, atrazine to release young conifers from a grass cover requires application of 4 pounds active ingredient (4 lb ai) per acre. Rates of application for these and other herbicides on a number of common silvicultural problems are suggested in appendix 1A.

In site preparation, however, less selective herbicides can be used; and some herbicides can be applied at higher rates than those used in release sprays. Rates of application for phenoxy herbicides, for example, may be as high as 4 lb ae per acre. Beyond a critical minimum dosage, however, adding additional herbicide is not likely to do much good. It is better to increase the total volume of spray and improve spray coverage by increasing the amount of carrier—which usually costs less and results in better control.

Volume of Spray

Volume of spray applied per acre is primarily dependent upon height and density of brush species and weed trees. The greater the density or the taller the height, the larger the volume of spray required to obtain adequate coverage.

Volume of aerial spray in most cases has been standardized at 10 gallons per acre. This can be varied, however, depending upon height and density of the brush cover. Small scattered shrubs may be satisfactorily killed with as little as 5 gallons per acre; while tall, dense stands of weed trees and brush species may require 10 or even 15 gallons of spray per acre. When D8 or similar nozzles are used on helicopters, 10 gallons of spray allows cross-flying or double flying the area to insure uniform application with a minimum of skips and misses (fig. 8).

Figure 8.—Helicopter applying 5 gallons of herbicidal spray per acre; the second 5 gallons per acre will be applied at right angles to the initial lines of flight.

Carriers

For aerial application, herbicides are diluted in one of three carriers: (1) oil, (2) water, or (3) oil-in-water emulsions. The carriers may be considered biologically inactive and form 80 to 95 percent of the spray volume, improve spray coverage, and allow uniform distribution of the small amount of active ingredient over a large area in herbicidal sprays. Another prime function of the carrier is to insure that a maximum amount of herbicide enters the plant.

Choice of carrier depends primarily upon species and season of application. Oil is used as the carrier in early spring at the beginning of the growing season, when herbicides must be absorbed through the bark of leafless stems and branches of deciduous species. Oil remains the preferred carrier during this season, even where some evergreen species are present in plant communities primarily composed of deciduous shrubs and weed trees. Water is the preferred carrier for herbicides to be absorbed from soil through roots or from foliage sprays on tender, immature leaves of deciduous species early in the growing season. Oil-in-water emulsions are used for foliage sprays that must be absorbed through heavily cutinized leaves of evergreen species or through hardened, mature leaves of deciduous species.

OIL CARRIERS

Esters, emulsifiable acids, and oil-soluble amines are applied in oil carriers when the major route of penetration is through the bark of stems and branches. Diesel oil or No. 2 fuel oil is the preferred carrier for early spring budbreak sprays on thin-barked deciduous species such as red alder and vine maple. Oil carriers penetrate the bark much more readily than water carriers. Since esters and other formulations named above are soluble in oil, they are carried through bark with the oil solute.

Oil carriers should not be applied on tender, new leaves during early spring. The leaves die too rapidly, minimizing absorption and translocation of the herbicide and reducing effectiveness of the spray treatment. Water carriers should be used in spring foliage sprays on deciduous species until almost all leaves are fully developed and hardened.

Mixing herbicides in the field is a relatively simple process, for almost all labels of commercial formulations bear specific instructions on how to mix the formulation with compatible carriers. A generally recommended procedure for mixing oil-soluble herbicides with oil carriers is:

1. Place one-fourth to one-third of the required volume of oil in the nurse tank on the truck.
2. Begin agitating and add the desired amount of oil-soluble herbicide to the oil in the nurse tank.
3. With continued agitation, add sufficient oil to obtain necessary volume of spray containing the desired ratio of herbicide:oil in the spray solution.

WATER CARRIERS

Esters, emulsifiable acids, and water-soluble amines should be applied in water carriers for foliage sprays on tender new leaves of deciduous species during the growing season. Since conifers are also highly susceptible to herbicides during this period, especially if oil is present in the carrier, water carriers are especially necessary if young conifers are to be released without damage. Water carriers are also specified for late summer sprays to release ponderosa pines from brush competition.

Use of water carriers may also be required because of physical characteristics of certain herbicidal formulations. Wettable powders such as atrazine and other soil-active herbicides that enter plants through root systems must be applied in water carriers during early spring, when sufficient rain will fall after application to leach the herbicides into the soil.

Procedures for field-mixing water-soluble herbicides or wettable powders in water carriers are exactly the same as those described for mixing oil-soluble herbicides in oil carriers. The only difference is that water is used instead of oil.

Low-volatile esters of phenoxy herbicide may also be applied in water carriers. Mixing procedures are exactly the same as for oil-soluble herbicides. However, esters are dissolved in special oils in commercial formulations, and they form a light, milky emulsion rather than a true solution when mixed with water. This does not affect either mixing procedures or aerial application in the field.

OIL-IN-WATER EMULSION CARRIERS

Esters of phenoxy herbicides may also be applied in oil-in-water emulsions, but the commercial formulation must contain an emulsifying agent to produce a stable emulsion. Oil-in-water emulsions are especially effective carriers on evergreen shrub and tree species (fig. 9), for even dormant season and early spring budbreak sprays are intercepted as foliage sprays (van Overbeek and Blondeau 1954, Gratkowski 1959). Emulsions are also used in late foliar and late summer applications on deciduous species, after leaves are fully developed and hardened. Since the herbicide must enter through a thick waxy cuticle, oil aids in wetting and penetration. However, if ponderosa pines are present or if other conifers are exposed and actively growing, water carriers must be used. Oil in the carrier would seriously damage the conifers (Gratkowski 1961b).

Oil-in-water emulsions with esters of phenoxy herbicides for aerial application usually contain ½ to 1 gallon of black diesel oil or No. 2 fuel oil in 10 gallons of spray per acre. Mixing procedure is as follows:

1. Fill the spray tank with about one-third the desired amount of water.
2. In a separate container(s), measure out the required amount of oil. Add the commercial formulation of esters to the oil and mix thoroughly.
3. Start agitation in the nurse tank and slowly add the oil-and-herbicide mixture to the vigorously agitating water in the nurse tank.

4. Continuing vigorous agitation, add the remainder of the water to obtain the required volume of spray mixture.

   Note: If commercial formulations contain an adequate amount of a good emulsifier, it may be possible to add the oil after the ester is mixed with the water in step 2. Continued vigorous agitation is necessary if this procedure is followed.

5. Continue agitation in the nurse tank for 15 to 20 minutes after step 4 before removing any spray for application. Also agitate the remaining spray in the nurse tank periodically to maintain a stable emulsion. With poor formulations or inadequate emulsifiers, the oil-herbicide droplets will tend to coalesce and rise to the surface—the emulsion breaks down and the oil-and-herbicide phase rises to the top of the water phase of the spray mixture in the nurse tank. Results obtained with separated spray mixtures will not be uniform or satisfactory.

Figure 9.—Young Douglas-fir released from evergreen shrubs and weed trees by one aerial spray of 2,4-D plus 2,4,5-T in an emulsion carrier.

Seasons of Application

Stage of plant growth and season of application are especially important in prescribing herbicidal treatments. Chemicals should be applied when undesirable plants are most susceptible and desirable species are relatively resistant or will sustain little damage. All plants exhibit seasonal changes in susceptibility to herbicides. Susceptibility of deciduous species is usually low during dormancy in late fall and winter, increases from time of budbreak throughout the growing season, and then decreases after growth has ceased. Conifers display similar but even more marked changes in susceptibility, with Douglas-fir, ponderosa pine, and sugar pine showing a rapid increase in resistance to phenoxy herbicides after cessation of growth and formation of new buds (Gratkowski 1970).

Correct timing in applying herbicidal sprays is especially necessary in releasing young conifers from brush competition without damaging the trees. Fortunately, phenological differences between hardwoods and conifers result in periods when brush species and weed trees are susceptible while conifers are resistant to herbicidal sprays. Successful release of young conifers from brush competition is based upon and exploits these differences in stages of growth and susceptibility to herbicides (fig. 10). Release sprays are applied when they will produce an acceptable kill of competing shrubs with minimum adverse effects on the trees.

Figure 10.—A single budbreak aerial application of 2,4,5-T will release this small Douglas-fir from the 15-foot-tall overstory of varnishleaf ceanothus without damaging the conifer.

Four periods are now recognized for silvicultural application of herbicides in Pacific Northwest forests. These are: budbreak, early foliar, late foliar, and late summer (table 4).

Table 4.--*Seasons for application of herbicides in Pacific Northwest forests*

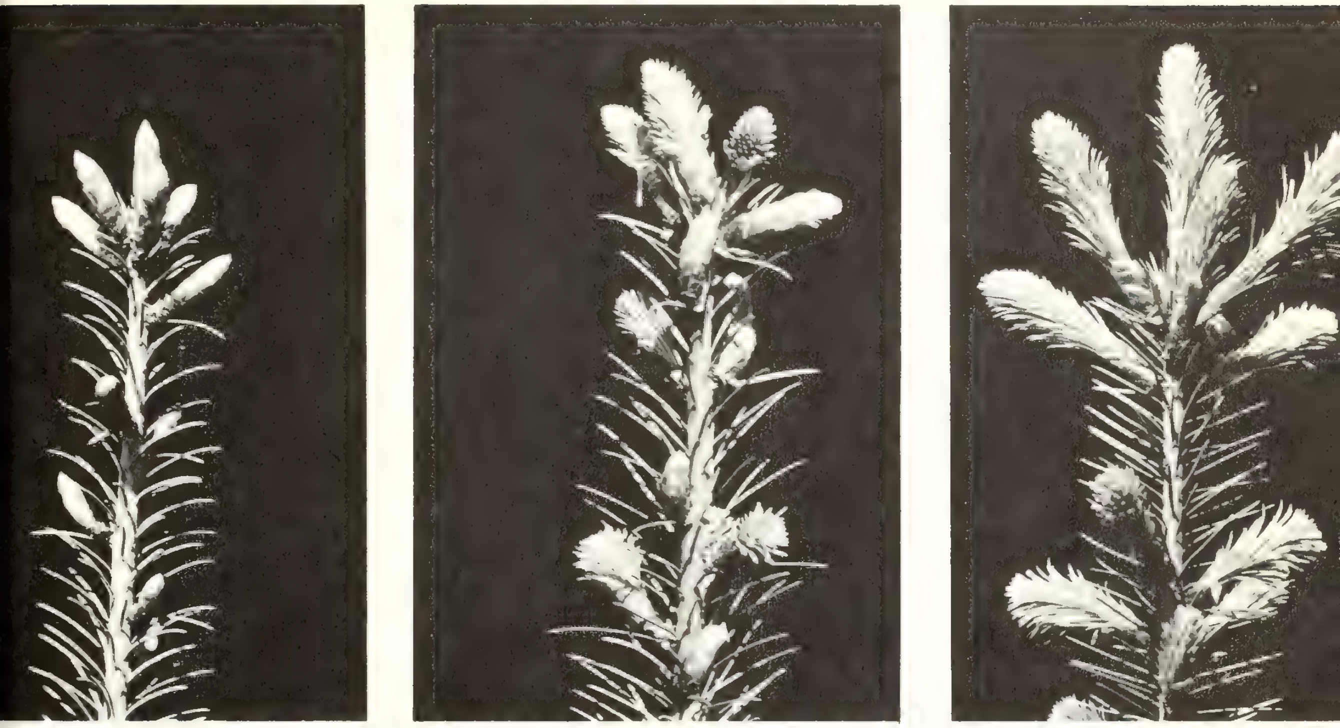
Season	Phenological description
DORMANT OR BUDBREAK	Late winter or early spring at beginning of spring flush of growth. Buds on conifers swelling or bursting; buds on shrubs and weed trees bursting or new leaves unfolding. Cease spray when new growth on conifers reaches 1 inch in length.
EARLY FOLIAR	Period of active growth; approximately three-fourths of new leaves on shrubs and weed trees full size. Period of maximum susceptibility to herbicides.
LATE FOLIAR	During midsummer, usually mid-July to early August, after cessation of growth on conifers, brush species, and weed trees. All leaves full size and hardened. New terminal buds well developed on both conifers and brush species.
LATE SUMMER	Usually late August to early September, long after cessation of spring flush of growth. Primarily a season for release of pines. DO NOT SPRAY IF LATE SUMMER GROWTH IS IN PROGRESS ON CONIFERS.

BUDBREAK SPRAYS

Luckily, early spring phenology of brush species and weed trees do not completely coincide with those of commercially important conifers in Pacific Northwest forests. Weed species generally begin growth and are susceptible to herbicides before budbreak on the conifers.

Budbreak sprays to release Douglas-fir, western hemlock, and other conifers are usually applied in late winter or early spring after brush species and weed trees begin growth, just before or during bud burst of the conifers. During this period, new leaves are beginning to form on the weed species–especially deciduous species–but absorption of herbicides is primarily through the bark of stems and branches. Most brush species and weed trees are susceptible to herbicides in oil carriers immediately after budbreak, while conifers are relatively resistant. As a result, budbreak sprays are one of the most effective treatments to release conifers from brush competition. To prevent damaging conifers, budbreak spraying should cease when new growth on Douglas-firs reaches 1 inch in length (fig. 11).

Figure 11.–Development of Douglas-fir buds allows accurate timing of budbreak sprays.



al spraying in progress . . . *. . . cease spraying* *. . . too late for aerial spraying*

If **DECIDUOUS SPECIES** are predominant or important components of the brushfield, a diesel oil carrier is used at this time of the year. The reason is that budbreak sprays are primarily intercepted by stems and trunks of deciduous species and the herbicide must penetrate and enter the plant through the bark of leafless stems and branches. Diesel oil is much more effective than either water or oil-in-water emulsion carriers in carrying esters of phenoxy herbicides through bark.

However, if brush or weed tree **EVERGREEN SPECIES** are predominant, an oil-in-water emulsion is just as effective; for the herbicides will be intercepted as foliage sprays and can enter the plant much more readily. An oil carrier is not necessary on evergreen species.

Release of ponderosa pines is an exception; pines cannot be released with budbreak sprays even in water carriers. In the Cascade Range in southwestern Oregon, young ponderosa pines became susceptible to damage from 2,4-D and 2,4,5-T in mid-February, 2½ months before bud elongation signalled the beginning of the spring flush of growth.[2]

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[2] H. Gratkowski, unpublished data.

EARLY FOLIAR SPRAYS

Early foliar sprays are applied in late spring after approximately three-fourths of the new leaves on brush species and weed trees are fully developed. All plant species are highly susceptible to herbicides during active growth, and this is one of the most effective periods for application of herbicides for site preparation. A light oil-in-water emulsion is frequently used as the carrier to obtain maximum effect of the herbicides.

This is a poor period for releasing conifers from brush and weed trees, for conifers also are most susceptible to herbicides during active growth. If any conifers are to be saved, minimum amounts of herbicide and water carriers must be used. In addition, the trees must be small and fully protected from the spray beneath the foliage of the shrub and weed tree overstory.

LATE FOLIAR SPRAYS

These are midsummer sprays applied after brush species have ceased active growth. All leaves are fully developed and hardened, and new terminal buds have been formed. During this period, most brush species are still photosynthetically active and accumulating food reserves, some of which are translocated to root systems for storage. Since phenoxy herbicides move in conjunction with carbohydrates in shrubs, there can be effective translocation of herbicides to the root systems as well.

Water carriers are generally used during this season. Emulsion carriers containing no more than ½ gallon of diesel oil per acre may be considered, but only if the trees will be protected from the spray by the brush canopy.

Although late foliar sprays are not as effective on shrubs as those applied during the growing season, this can be an effective season for releasing conifers from brush competition without damaging the trees. Conifer resistance to herbicides increases rapidly after cessation of growth and formation of new buds (Gratkowski 1970). Care must be exercised, however, on wet sites or if rain has fallen shortly before spraying or rainfall is imminent. Conifers may then experience a second flush of growth, again become susceptible to herbicides and be damaged by late foliar sprays.

LATE SUMMER SPRAYS

Late summer sprays are applied in late August or very early September, long after brush species and conifers have ceased growth, but at least 1 month before leaf abscission on deciduous species. This is one of the least effective periods for controlling brush species and weed trees with herbicides, but control of many species is still sufficient to allow safe and effective release of ponderosa and other pines.

Late summer has proved the only period when ponderosa and sugar pines can be safely released from brush competition with phenoxy herbicides (Gratkowski 1972). Both ponderosa and sugar pines are more sensitive than Douglas-firs to phenoxy

herbicides. Since pines are damaged less by 2,4,5-T than by 2,4-D, late summer sprays of 2,4,5-T in water carriers are used to release ponderosa pines from brush competition in southwestern Oregon.

This discussion of seasons for application of herbicides is meant to stress the point that seasons and stages of plant growth are an important key to safe and effective silvicultural use of herbicides. Also—as stated earlier—stages of growth of our conifers do not exactly coincide with those of our brush species and weed trees. The conifers do not begin growth as early as most brush species in spring and show a much more rapid increase in resistance to herbicides after cessation of growth.

Except for pines, two periods—budbreak in early spring and late foliar during midsummer—allow maximum safety in releasing conifers from brush and weed tree competition. Good kills can be achieved on brush species and weed trees with little or no damage to the conifers. For pines, late summer is the only safe period for release with aerial sprays.

Prescribing Herbicidal Treatment

A vital decision in prescribing any herbicidal treatment is selection of a herbicide or combination of herbicides that will adequately control the most abundant species on the area to be treated. That choice will usually be dictated by two to four species that provide 75 percent or more of the cover. Although controlling these species would be sufficient for release or even for site preparation on most areas, many minor species will also be affected by the same herbicides—providing an even greater degree of control.

During the past 25 years, a great number of studies have been conducted to determine the most effective herbicides to control native shrubs, weed trees, and grasses. Many publications provide results of this research and are available to guide selection of effective chemicals. Those considered most useful for silviculturists are listed in Literature Cited on pages 26 to 28. Publications are available for shrubs of central Oregon (3,4,7,9,11,16), for western Oregon and Washington (5,6,7,14,16,25, 26,27,30,31,32,33,34,35,36) and for southwestern Oregon (7,8,9,10,11,12,13,16, 18,20,25,26,27). Effects of herbicides on conifers are described in publications 3,9, 10,14,21,23,25,31,33, and 34. Information on grass control in western Oregon is available in publications 28,29, and 36.

Cooperative research and field trials based upon such data have produced effective herbicidal treatments for many silvicultural problems on Pacific Northwest forest lands. Many are described in the literature (6,10,11,15,16,17,18,20,24,25,29, 32,33,34,37).

Aerial application of herbicides is often combined with prescribed burning or mechanical eradication for site preparation. Aerial spraying followed by prescribed burning has been discussed in other articles (1,8,16,20) and aerial spraying combined with mechanical eradication (1,16,17,32).

Herbicidal treatments for many common silvicultural problems are provided in appendix 1A of this paper. Others may be found in some of the publications listed in Literature Cited. Tentative treatments for special problems not covered in either source may be developed by considering the factors described earlier and modifying the basic treatments provided in appendix 1A.

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Appendix 1

A. Aerial Spray Treatments to Release Conifers and Control Brush in Pacific Northwest Forests

This section offers herbicidal prescriptions for some common silvicultural problems encountered on Pacific Northwest forest lands. These prescriptions are considered the best that have been developed for the species and brush types specified based upon extensive research by Federal, State, and industrial forestry organizations. Some were modified or developed by practicing foresters for particular combinations of species, vegetation, and site conditions. All have been tested, developed, and modified in silvicultural application during the past 20 years.

As stated earlier, a herbicidal treatment for any given site must be keyed to species composition and designed to achieve the desired silvicultural objective. The Pacific Northwest presents an unusually large variety of topographic, geographic, and climatic conditions; and this great diversity in habitats is reflected in the vegetation of our forests. As a result of this diversity, silviculturists are faced with many different problems. Although the number of suggested treatments in this section may seem excessive, a half dozen manual-type prescriptions cannot be expected to meet all needs. Even those presented will not provide answers for a number of important silvicultural problems.

Douglas-fir, Hemlock, and Spruce Release

All treatments in this section are on a "per acre" basis to release Douglas-firs, hemlock, and Sitka spruce.

VINE MAPLE. Acceptable kill to release Douglas-firs from vine maple has been obtained only with early spring aerial application of low volatile esters of 2,4,5-T in diesel oil. The spray is applied just before or during bud burst of Douglas-firs. An oil carrier is a necessity, for vine maple is leafless at this time and the herbicide is actually applied as a stem spray that must enter through the bark. Foliage spraying in late spring through summer is relatively ineffective on vine maple. Treatment per acre consists of the following:

2,4,5-T	2 lb ae
Diesel oil	9½ gal of black diesel or No. 2 fuel oil

RED ALDER. Two types of treatment may be designated to release Douglas-firs from red alder. The choice depends upon height of the alder when treated. If alder is 15 feet or less in height, a single budbreak spray will usually be sufficient. If alder exceeds 15 feet in height, two sprays may be needed: (1) a budbreak spray in an oil carrier, and (2) a late foliar spray in a water carrier. The treatments are designated below:

1. Alder 15 feet or less in height:

Dormant spray

2,4-D	1 lb ae	(Use a commercial brushkiller formulation)
2,4,5-T	1 lb ae	
Diesel oil	9½ gal	

Season: Apply just before or as Douglas-firs burst their buds in early spring. Diesel oil carrier needed to carry herbicide through bark of stems and trunk, since alder is leafless at this time of year. Cease spraying when new growth on Douglas-firs reaches 1 inch in length.

Note: The Weyerhaeuser Company sometimes uses an early foliar spray of 1 lb of 2,4-D plus 1 lb of 2,4,5-T in a water carrier, but stops spraying when new leader growth on the Douglas-firs exceeds 2 inches in length. I would recommend, however, that an early foliar spray such as this should not be used unless the conifers are well shielded from the spray by alder foliage. If conifers are exposed, they may sustain damage. Foresters should consider the fact that any dead tissue on conifers is undesirable and may serve as an entry court for disease.

2. Alder more than 15 feet fall: two sprays required.

Dormant spray

2,4-D	1 lb ae	(Use a commercial brushkiller formulation)
2,4,5-T	1 lb ae	
Diesel oil	9½ gal	

Season: Apply just before or as Douglas-firs burst their buds in early spring. Diesel oil carrier needed to carry herbicide through bark of stems and trunk, since alder is leafless at this time of year.

Late foliar spray

2,4-D	2 lb ae
Water	to make 10 gal of spray per acre

Season: Apply in July after alder has ceased active growth, all leaves are full size and hardened, and terminal buds have been formed. Do not use oil in the carrier unless the conifers will be protected from the respray by foliage of the alder overstory.

Note: This late foliar respray should be applied 1 to 2 years after the initial spray. Respray when alder has enough foliage to intercept most of the foliar spray.

RHODODENDRON. This species is more difficult to control, but the following treatment is sometimes used where density of the shrubs is sufficient to require control in order to release young Douglas-firs. It should also be considered for site preparation on such areas when conifers are to be interplanted to increase stocking. Treatment per acre:

2,4-D	2 lb ae	(Use a commercial brushkiller formulation
2,4,5-T	2 lb ae	of 2,4-D and 2,4,5-T)
Diesel oil	½ gal	
Water	to make 10 gal spray per acre	

Note: If using a 6 lb/gal commercial formulation (3 lb of 2,4-D plus 3 lb of 2,4,5-T), add 1 pt of Multi-film X-77 surfactant to each 100 gal of spray.

Season: Apply as a budbreak spray during early spring, just before or as vegetative buds burst on Douglas-firs. Retreatment will be necessary.

SNOWBRUSH, BLUEBLOSSOM, VARNISHLEAF, AND MOUNTAIN WHITETHORN CEANOTHUS. These species respond well to low volatile esters of 2,4,5-T applied from early spring throughout the growing season. In release projects, carriers are varied to fit physiological condition of the conifers and their degree of protection from spray beneath the shrub canopy. Ceanothus species should be treated before the shrubs exceed 4 to 5 feet in height. This will minimize damage to conifers among the shrubs when the shrubs break off and fall.

1. Ceanothus shrubs 5 feet or less in height:

2,4,5-T	2 lb ae
Diesel oil	3/4 gal
Water	to make 8 to 10 gal of spray per acre

Note: If using a 6 lb ae/gal commercial formulation of 2,4,5-T, add 1 pt of Multi-film X-77 surfactant per 100 gal of spray.

Season: Apply during budbreak, just before conifers burst buds or even while buds are swelling. Can also be used during late spring and summer, if conifers are overtopped and well shielded from the spray by ceanothus foliage. If an appreciable number of conifers will be exposed, the budbreak spray is preferred. If a water carrier (no diesel oil) must be used during the growing season, cease spraying when new growth on the conifers reaches 1 inch in length.

In dormant (bud burst) spraying, low volatile esters of 2,4,5-T can also be applied in a straight diesel oil carrier rather than in the oil-in-water emulsion given below. This would consist of:

2,4,5-T	2 lb ae per acre
Diesel oil	to make 10 gal of spray per acre

This treatment is especially useful in a mixture of deciduous species such as vine maple or alder with evergreen brush species. An oil carrier is necessary to get the herbicide through the bark of stems on leafless deciduous species at this time of year. And vine maple *must* be sprayed at this time of the year.

2. Taller ceanothus, with Douglas-firs and other conifers intertwined with the ceanothus stems. If ceanothus shrubs like this are killed, they will usually rot at the root crown and break off and fall as a clump, carrying many of the intertwined conifers with them. These trees will not recover unless manually released from the fallen brush within the first year after the shrubs break down.

   To minimize damage to conifers intertwined with tall ceanothus shrubs, a very light dosage of herbicide is advised. Its objective is to obtain a high percentage of defoliation, to kill back the stems one-third or one-half of their length, but to maintain life in the lower portion of the stems and especially the root crown. The purpose is to prevent the root crown from rotting and having the entire shrub fall, carrying the intertwined trees with them. If new foliage develops on the living portions of the stem, it can be desirable. It may reduce basal sprouting and slow regrowth of the shrubs. The recommended treatment per acre for tall ceanothus is as follows:

2,4,5-T	3/4 lb ae
Diesel oil and	3/4 gal
Water	to make 10 gal of spray per acre

CHINKAPIN. This species resprouts abundantly after initial treatment of mature shrubs, and repeated treatments are needed to get a high percentage of kill. However, this treatment (with followup spraying where observation indicates necessity) is used to release Douglas-firs:

2,4,5-T	2 lb ae
Diesel oil	1 gal
Water	to make 10 gal of spray per acre

Season: Apply when buds are swelling or bursting on Douglas-firs during early spring.

Note: Again, if using a 6 lb ae/gal commercial formulation of 2,4,5-T, add 1 pt of Multi-film X-77 or similar surfactant.

SALMONBERRY. To release Douglas-fir, hemlock, or Sitka spruce, three treatments are available. One involves use of amitrole-T; the other two involve use of 2,4,5-T. All are applied as foliage sprays.

1. *Late foliar spray.* These sprays are usually applied during the latter half of July. This is the preferred treatment, especially since thimbleberry usually is found with salmonberry. A late foliar spray with 2,4,5-T will also provide good control of thimbleberry and prevent its occupying areas where the

salmonberry has been eliminated. Care should be taken not to apply the treatment on any area where conifers still show active growth.

2,4,5-T	3 lb ae
Diesel oil	½ gal
Water	to make 10 gal of spray per acre

Season: Late foliar.

2. *Early foliar spray.*

Amitrole-T	2 lb (1 gal) per acre
Water	to make 10 gal of spray per acre

Season: Apply while salmonberry is growing. Good results obtained on the Siuslaw National Forest when applied in mid-June. May cause some damage in foliage of exposed conifers.

3. *Early foliar spray.* Use only if the young conifers are well shielded from direct application of the spray by salmonberry foliage. Do not apply after new growth on the conifers exceeds 1 inch in length.

2,4,5-T	2 lb ae
Water	to make 10 gal of spray per acre

Season: Early foliar.

TANOAK, MADRONE, CANYON LIVE OAK, AND MANZANITA.

To release: Douglas-fir, hemlock, Sitka spruce, or grand fir

2,4-D	3 lb ae
Diesel oil	3 qt
Water	to make 10 gal of spray per acre

Season: Budbreak; apply just before or during budbreak on Douglas-firs.

ALDER, VARNISHLEAF CEANOTHUS, CHINKAPIN, AND VINE MAPLE (Southwest Oregon Coast Ranges).

To release: Douglas-fir, Sitka spruce, and hemlock

2,4,5-T	2 lb ae
Diesel oil	to make 10 gal of spray per acre

Season: Budbreak; apply just prior to or at time of bud burst on Douglas-firs during early spring.

DECIDUOUS OAKS (Oregon white and California black oaks).

To release: Douglas-fir

2,4,5-T	2 lb ae
Diesel oil	2 qt
Water	to make 10 gal of spray per acre

Season: Early foliar, after at least three-fourths of the oak leaves are full size. Conifers should be well shielded from the spray by oak foliage; exposed conifers are apt to be damaged. If many conifers are exposed, do not spray after new growth exceeds 1 inch in length.

Cut surface treatment: To release fir or pine. Hack-squirt oaks with 2,4-D amine with cuts spaced no more than 1½ inches apart. Apply 1 to 2 ml of amine per cut. Best results if treated during growing season.

DECIDUOUS BRUSH AND TREES (especially willow, cherry, and elderberry).

To release: Douglas-fir, Sitka spruce, and hemlock

2,4-D	1 lb ae
2,4,5-T	1 lb ae
Water	to make 10 gal of spray per acre

Season: Early foliar during spring, after most new leaves are fully developed. Cease spraying when new growth on conifers reaches 1 inch in length. If conifers will not be shielded from the spray by foliage of the deciduous overstory, use a late foliar spray in midsummer.

Pine Release

MIXED DECIDUOUS BRUSH.

To release: ponderosa pines

2,4,5-T	1½ lb ae
Water	to make 8 to 10 gal of spray per acre

Season: Late August to early September

BROADLEAF EVERGREEN BRUSH AND WEED TREES (except manzanitas).

To release: ponderosa pines

2,4,5-T	2 lb ae
Water	to make 10 gal of spray per acre

Season: Late August to mid-September

CEANOTHUS (deciduous and evergreen species).

To release: ponderosa pines

2,4,5-T	2 lb ae
Water	to make 10 gal of spray per acre

Season: Late August to mid-September

DECIDUOUS OAKS (Oregon white and California black oaks).

To release: ponderosa pines

2,4,5-T	2 lb ae
Water	to make 10 gal of spray per acre

Season: Late summer spray during late August to early September

POISONOAK, PACIFIC. Usually Douglas-firs and ponderosa pines are found intermixed with poisonoak only at low elevations or on dry sites.

To release: Douglas-firs. Two treatments are possible.

1. The preferred treatment would be:

2,4,5-T	2 lb ae
Water	to make 8 gal spray per acre

Season: Late foliar

Note: A small amount (1 to 2 qt) of diesel oil may be added, if the trees will be shielded from the spray by the brush overstory.

2. Less desirable would be:

Amitrole-T	1 gal
Water	to make 8 gal spray per acre

Season: Early foliar. May cause some yellowing and defoliation of Douglas-fir.

To release: ponderosa pines

2,4,5-T	2 lb
Water	to make 8 gal spray per acre

Season: Late summer foliage spray, at least 1 month before abscission begins.

B. Site Preparation Treatments for Brush Control on Nonstocked Sites

Timing is not as critical in spraying nonstocked sites as when spraying for conifer release. These treatments may be applied at any time from bud burst on the brush species and weed trees through late June. The brush species will be physiologically active during this period,and herbicidal sprays will be most effective throughout that season.

ALDER. Two types of treatments are possible depending upon height of alder to be treated. If alder is 15 feet or less in height, a single budbreak spray will usually be sufficient. If alder exceeds 15 feet in height, two sprays will probably be

required: (1) a budbreak spray in an oil carrier, and (2) a late foliar spray in a water carrier after the area has been planted. These treatments are designated below:

1. Alder 15 feet or less in height:

   Dormant spray

2,4-D	1 lb ae	(Use a commercial brushkiller formulation)
2,4,5-T	1 lb ae	
Diesel oil	9½ gal	

   Season: Budbreak; new alder leaves beginning to uncurl, but few full-sized, tender, new leaves.

2. Alder more than 15 feet fall. Two sprays are required.

   Dormant spray (plant area as soon as possible after applying this initial treatment).

2,4-D	1 lb ae	(Use a commercial brushkiller formulation)
2,4,5-T	1 lb ae	
Diesel oil	9½ gal	

   Season: Budbreak; new alder leaves beginning to uncurl, but few full-sized, tender, new leaves.

   Late foliar respray

2,4-D	2 lb ae
Water	to make 10 gal of spray per acre

   Season: Apply in July after alder has ceased active growth, when all leaves are full sized and hardened and terminal buds have been formed. Do not use oil in the carrier. This late foliar respray should be applied 1 or 2 years after the initial spray. The alder should have enough foliage to intercept sufficient spray to increase alder kill to the point where no additional sprays will be needed.

   Note: If salmonberry and thimbleberry have grown rapidly after the initial spray and have developed a dense canopy over the newly planted conifers, use the following spray treatment:

2,4,5-T	3 lb ae
Diesel oil	½ gal
Water	to make 10 gal of spray per acre

   Season: Late foliar. Apply in July after alder has ceased active growth, all leaves are full size and hardened, and terminal buds have been formed. This treatment should not only control the alder, it should release the young conifers from salmonberry and thimbleberry as well.

DECIDUOUS HARDWOODS (mixed brush and/or trees). Apply during late spring, after most new leaves are full size, but during period of active growth on all species. Amount of herbicide and the carrier may be varied depending upon species, height, and density of the stand. Low, open stands should get less herbicide.

2,4-D	1½ lb ae
2,4,5-T	1½ lb ae
Diesel oil[1]	½ gal
Water	to make 10 gal of spray per acre

CEANOTHUS (all species). Most susceptible during active growth from early spring to early July.

2,4,5-T	2 lb ae
Diesel oil	3 qt
Water	to make 10 gal of spray per acre

Season: Early foliar, during active growth.

DECIDUOUS, EVERGREEN, OR MIXED DECIDUOUS AND EVERGREEN. For brushfields or mixed brush and weed trees. Dow Chemical Company reports its Esteron 245 label registered with the Environmental Protection Agency allows use of the following combination.[2] It should be used *only for site preparation.*

Picloram	2 gal Tordon 101
2,4,5-T	4 lb ae (1 gal Esteron 245)
Water	to make 10 gal spray per acre

Season: Early foliar

Note: I consider this an excessive dosage per acre of both herbicides. Efforts are being made to obtain registrations that will allow use of lower rates of these herbicides in combination for site preparation.

BROAD-SCLEROPHYLL CHAPARRAL AND BROAD-SCLEROPHYLL FORESTS. In these types in southwestern Oregon, the spray treatments suggested for release of Douglas-fir can also be used for site preparation. In the extensive tanoak, madrone, canyon live oak, and manzanita brush type, the treatment listed for releasing Douglas-firs, etc., is as good as any that can be suggested.

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[1] Diesel oil should be used only on tall, dense stands or late in the season, after most leaves have hardened.

[2] This claim was checked with and verified by the Environmental Protection Agency.

Appendix 2
List of Trees and Shrubs

TREES

Scientific name	Common name
Abies concolor	fir, white
Abies magnifica var. *shastensis*	fir, Shasta red
Alnus rubra	alder, red
Arbutus menziesii	madrone, Pacific
Castanopsis chrysophylla	chinkapin, golden
Libocedrus decurrens	incense-cedar
Lithocarpus densiflorus	tanoak
Picea sitchensis	spruce, Sitka
Pinus contorta	pine, lodgepole
Pinus lambertiana	pine, sugar
Pinus ponderosa	pine, ponderosa
Pseudotsuga menziesii	Douglas-fir
Tsuga heterophylla	hemlock, western
Tsuga mertensiana	hemlock, mountain

SHRUBS

Acer circinatum	maple, vine
Amelanchier alnifolia	serviceberry, Saskatoon
Arctostaphylos canescens	manzanita, hoary
Arctostaphylos columbiana	manzanita, hairy
Arctostaphylos hispidula	manzanita, Howell
Arctostaphylos patula	manzanita, greenleaf
Castanopsis chrysophylla var. *minor*	chinkapin, goldenevergreen
Castanopsis sempervirens	evergreenchinkapin, Sierra
Ceanothus cordulatus	ceanothus, mountain whitethorn
Ceanothus integerrimus	ceanothus, deerbrush
Ceanothus thyrsiflorus	ceanothus, blueblossom
Ceanothus velutinus	ceanothus, snowbrush
Ceanothus velutinus var. *laevigatus*	ceanothus, varnishleaf
Corylus cornuta var. *californica*	hazel, California
Lithocarpus densiflora var. *echinoides*	tanoak, scrub
Quercus chrysolepis	oak, canyon live

Rhododendron macrophyllum	rhododendron, Pacific
Rhus diversiloba	poisonoak, Pacific
Rubus parviflorus	thimbleberry
Rubus spectabilis	salmonberry
Salix spp.	willow
Sambucus cerulea	elderberry, blue
Sambucus racemosa	elderberry, red

Appendix 3
Glossary of Agricultural Chemical Terms

Acid equivalent – Amount of active ingredient expressed in terms of the parent acid.

Active ingredient – An ingredient which provides stimulating or killing action. In herbicides, this is equivalent to the amount of technical material with herbicidal action in a formulation.

Adjuvants – Additional compounds added to the herbicide. These act as wetting or spreading agents, stickers, penetrants, emulsifiers, etc., changing physical characteristics of the toxic materials to make them easier to handle, mix, and apply in the field.

Aerial spray – Broadcast aerial application of a herbicide as a solution, emulsion, or wettable powder as a spray applied from helicopters or fixed-wing aircraft.

Annual – A plant that completes its life cycle in 1 year.

Aromatics – Oil or oil-like materials that burn tops of weeds. Sometimes used in formulating herbicides.

Basal spray – Application of a coarse-droplet spray at low pressure on the basal portion of stems to a height of 12 to 18 inches above the soil surface. Spray is applied until an excess runs off onto the soil surface at the base of the stem.

Broadcast spray – Application over an entire area rather than in bands or strips. All exposed stems and foliage visible from above receive treatment.

Broadleaf plants – Usually refers to herbaceous plants with broad, flat leaves as opposed to grasslike plants with very narrow leaves.

Brush control – Control of woody plants.

Carrier – A liquid or solid material added to a herbicidal chemical or formulation to allow easier mixing, storage, shipment, and application in the field. In this publication, the term refers especially to oil, water, or both added to the commercial formulation to increase its volume and allow application of small amounts of active ingredient over a large area. (Also see "Diluent.")

Compatible – Two or more compounds or products that can be mixed without detrimentally affecting their performance.

Concentration – Refers to the amount of active material in a given weight of a mixture or volume of a solution. Recommendations and specifications for concentration of agricultural chemicals are frequently given in terms of pounds acid equivalent or active ingredient per unit volume of spray mixture or solution.

Conifer A tree or shrub of the order Gymnospermae, mostly evergreens bearing true cones (hence, conifers) and needle-shaped or scalelike leaves. In forestry, generally tree species producing timber known as softwood.

Contact herbicide – One that kills primarily by contact with plant tissue rather than as a result of translocation. Only that portion of a plant contacted is directly affected. Young seedlings are killed, but perennials may recover from the uninjured parts below the soil surface. On woody plants, contact herbicides usually kill only the leaves and very tender stem tips without damaging the main portion of the living stems.

Cuticle – A nonliving outer waxy layer covering all or part of a leaf.

Deciduous – Plants which normally lose their leaves during the winter.

Defoliant – A material that causes the leaves or foliage to fall from plants.

Delayed action – As opposed to immediate effect. With some herbicidal chemicals (i.e., 2,4-D; 2,4,5-T; MCP; or dalapon) delayed response is expected. Considerable time may elapse before maximum effects are observed. Usually treated plants stop developing soon after treatment, then gradually die.

Desiccant – A plant drying agent. Usually the foliage is killed quickly by contact action, but this category of herbicides may include slower acting chemicals such as the phenoxy herbicides.

Detergent – Any liquid or solid material that will remove residues from application equipment, such as a dishwashing or laundry detergent.

Diluent – Any liquid or solid material used to dilute the technical toxicant or herbicide to field strength for mixing and dilution to allow adequate plant coverage. (See also "Carrier.")

Dinitro (=dinoseb) – A common designation for dinitro-phenols. These materials are used as contact herbicides to cause rapid defoliation.

Dissolve – Usually refers to getting solids into solutions in a solvent; requires the breaking apart of solids into molecules, ions, or other fractions of the solid molecules in the solvent.

Dormancy – The term describing the temporary suspension of visible growth.

Dormant spray – Application of chemical in winter or very early spring before treated plants show any evidence of active growth.

Drift – Movement of airborne particles as dust, fine droplets, mists, aerosols, or vapors from the intended target area to other areas.

Emulsifying agent – A material which helps to suspend globules of one liquid in another, i.e., oil-in-water.

Emulsion – A mixture in which one liquid is suspended as minute globules in another liquid. Example: butterfat globules in milk, or a suspension of oil droplets in water.

Epinasty – Twisting or curling of leaves and stems caused by uneven growth of plant cells. This is a characteristic reaction from treatment with 2,4-D and other growth regulator herbicides.

Eradication – Complete elimination of a living organism from a specified area.

Flagging – Production of a reduced number of new leaves (often small and deformed) on partially killed stems and crowns of shrubs and weed trees treated with herbicides.

Formulation – A mixture of an active herbicidal chemical with carriers, diluents, or other materials; usually to facilitate handling, mixing, effectiveness, and application in the field.

Granules – A type of formulation in which the active ingredient is usually mixed and pressed with an inert carrier to form a small pellet.

Growth regulator – A chemical or herbicide, which, when applied in small amounts to leaves, stems, or roots, alters the normal growth and form of the plant. Phenoxy herbicides are classified as growth regulators.

Herbaceous – A plant that remains soft or succulent and does not develop woody tissue.

Herbicide – A phytotoxic chemical used for killing or inhibiting (stunting) the normal growth and development of a plant.

Hormone – A growth regulating substance occurring naturally in plants that controls growth or other physiological processes. Also refers to certain manmade or synthetic chemicals which regulate growth activity. Such manmade chemicals, however, are more correctly called synthetic regulators; they are not true plant hormones.

Humidity – Refers to moisture or dampness in the air. Weed killers are often more effective under moderately humid conditions. In areas or at times when humidity is very low, high herbicidal rates or high volumes of carrier may be required because sprays dry more quickly and absorption is poor.

Hydrocarbons – Compounds that contain carbon and hydrogen only.

Inert ingredient – Any ingredient in a formulation which has been added for other than its pesticidal action.

Invert emulsion – One in which the water is dispersed in oil rather than oil in water. Oil forms the continuous phase with water dispersed throughout the oil. Usually this produces a thick, mayonnaiselike mixture.

Label – All written, printed, or graphic matter on or attached to the herbicide container as required by law.

Leach – Usually refers to the movement of chemicals through a soil by or with an amount of water that is in excess of the soil's moisture-holding capacity. May also refer to movement of herbicide out of leaves, stems, or roots into the air or soil.

Miscible – Capable of being mixed, usually with another liquid. Example: water and alcohol.

Necrosis – The death of tissue, such as all or part of a plant.

Nonselective herbicide – Formulations of herbicides that destroy or prevent plant life in general without regard to species. Soil sterilants are classified as nonselective herbicides, although one or more species on an area may not be controlled even by such herbicides.

Noxious weed – A weed arbitrarily defined by law as being especially undesirable, troublesome, or difficult to control.

Oils – Usually refers to aromatic or paraffinic oils used as diluents in formulating products, as diluents or carriers for herbicides, or for direct use as herbicides. (Also see "Aromatics.")

Oral toxicity – Toxicity of a compound when it is ingested.

Organic compounds – Chemical compounds with molecules containing several carbon atoms.

Perennial – A plant that lives for many years. The tops may die back in winter or in severe drought, but the roots or rhizomes persist.

Persistence – Refers to the length of time that a herbicide remains active and phytotoxic in a plant or soil.

Pesticide – Any substance or mixture of substances intended for controlling insects, rodents, fungi, weeds, and other forms of plant or animal life that are considered to be pests. A broad classification including herbicides.

Pesticide tolerance – The amount of pesticide residue which may legally remain in or on a food crop. Federal residue tolerances are established by the Environmental Protection Agency.

Photosynthesis – The manufacture of simple sugars by green plants utilizing light as the energy source.

Phytotoxic – Poisonous or injurious to plants.

Postemergence treatment – Treatments made after plants emerge above the soil. Generally refers to weed control procedures in reference to time of application of a herbicide.

Preemergence treatment – Treatment made before weed species emerge above the soil surface.

Rate or dosage – These terms are synonymous. "Rate" is the preferred term. Rate usually refers to the amount of active ingredient of a herbicide (such as 2,4-D acid equivalent) applied to a unit (such as 1 acre) regardless of percentage of chemical in the carrier.

Registered – Pesticides that have been approved for use by the Environmental Protection Agency or by a State Department of Agriculture.

Residual – To have a continued killing effect over a period of time.

Residue – That amount of active pesticide that is on or in plants, animals, or other life forms, or in water or soil at the time a sample is taken and analyzed.

Residue tolerance – The amount of pesticide residue which may legally remain in or on a food crop.

Resistance – The ability of an organism to withstand, reduce, or suppress the injurious effects of a pesticide.

Selective herbicide – One which is more toxic to some species of plants than others. Thus, weeds may often be controlled without significant damage to trees or other plants by selective herbicidal action.

Sensitivity – Susceptibility of a species to effects of a toxicant at low dosage; not capable of withstanding effects. For example, many broadleaved plants are sensitive to 2,4-D.

Silvicide – A herbicide used to control trees.

Soil sterilant – A herbicide, which when present in or on the soil prevents the growth of plants. Sterilization may be temporary or relatively permanent.

Solubility – The amount of a substance which will dissolve in a given amount of a specified liquid.

Solution – Should be used only to describe a formulation in which the ingredients are dispersed throughout the solvent in an ionic or molecular state.

Solvent – A liquid which will dissolve a substance forming a true solution (generally a molecular or ionic dispersion in the liquid solvent).

Species – A group of individuals similar in structure and physiology capable of interbreeding and producing fertile offspring which are like their parents.

Spot treatment – Application of herbicides as sprays, granules, or powders to a restricted area or individual plants as differentiated from overall, broadcast, or complete coverage.

Spreading agent – A substance used to improve the wetting, spreading, or possibly the adhesive properties of a spray.

Stem – Those parts of a plant which support leaves, flowers, or roots. The main plant framework.

Sterilant – A chemical used to render the soil barren of all plants for a certain length of time.

Surface tension – Due to molecular forces at the surface, a drop of liquid forms an apparent membrane that causes it to ball up rather than to spread as film. This molecular force or attraction is termed surface tension.

Surfactant – A material used in herbicidal formulations to impart emulsifiability, spreading, wetting, dispersibility, or other surface-modifying properties to the formulation.

Suspension – Particulate matter dispersed and suspended in a liquid as contrasted to a true solution, e.g., diuron, atrazine, or simazine wettable powders in water and slurries.

Synergism – A cooperative action of different chemicals so that their total activity, in this case control effectiveness, is greater than the sum of their individual effects on the plant.

Systemic – Any chemical that, when absorbed into one part of a plant or other organism, becomes distributed throughout the organism; for example, phenoxy herbicides.

Tolerance – (pesticide) – The amount of pesticidal chemical allowed by law to be in or on plant or animal products sold for consumption. (See also "Residue tolerance.")

Tolerant – Capable of withstanding the effects of herbicides. For example, grass is tolerant of 2,4-D to an extent that allows this herbicide to be used selectively to control broadleaved weeds without killing the grass.

Toxic – Poisonous or injurious to animals and plants through contact or systemic action.

Toxicity – Degree to which something is poisonous to a life form.

Translocation – Transfer of food or other materials, such as 2,4-D, from one part of a plant to another. (See also "Systemic.")

Volatile – A compound is said to be volatile when it evaporates or is vaporized (changes from a liquid or solid to a gas) at ordinary temperatures on exposure to air.

Weed – Any plant growing where not wanted.

Wettable powder – A powder that will readily form a suspension in water.

Wetting agent – A compound added to a spray formulation to cause the spray droplets to spread and more thoroughly and uniformly wet plant surfaces.

Woody plants – Plants that develop woody stems.

GPO 994-472

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key--out of reach of children and animals--and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

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1975
USDA Forest Service General Technical Report PNW-38

Research Natural Area Needs in the Pacific Northwest

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Forest Service, U. S. Department of Agriculture
Portland, Oregon

Abstract

Research Natural Areas are examples of typical and distinctive natural ecosystems and habitats reserved for scientific and educational use. This outline of the minimal Research Natural Area system needed to provide adequate field laboratories for ecological, environmental, and land management research was developed by an interinstitutional, interdisciplinary working group. Natural area needs were first described on the basis of individual organisms, habitats, or ecosystems which should be represented. These "cells," the basic building blocks in defining the total scope of the system, considered terrestrial and aquatic environments as well as rare and endangered species. Identified cells were matched against existing Research Natural Areas to determine which were already filled. The remaining, unfilled cells were then tentatively grouped as units which were listed as Research Natural Area needs.

A minimal Research Natural Area system for Oregon and Washington requires approximately 360 tracts which, in turn, incorporate over 770 individual cells (ecosystems, habitats, or organisms). Since 60 Research Natural Areas are already established, about 300 additional areas are needed. These remaining needs were assigned a priority (low, medium, or high) based on importance and degree to which they are endangered, as well as identified as to the Federal, State, or private agency or institution most likely to be able to provide a tract of that type.

The purpose of Research Natural Areas, their place in land planning, history of Research Natural Area activities in the Pacific Northwest, and general observations and recommendations on unresolved problems are also outlined.

Keywords: Research Natural Area, scientific preserves, natural ecosystems, endangered species, Oregon, Washington.

RESEARCH NATURAL AREA NEEDS IN THE PACIFIC NORTHWEST
A Contribution To Land-Use Planning

C. T. Dyrness, Jerry F. Franklin, Chris Maser,
Stanton A. Cook, James D. Hall, and Glenda Faxon

Report on Natural Area Needs Workshop
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1975

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE PORTLAND, OREGON

FOREWORD

Research Natural Areas are important elements in land-use plans. They may be called Research Natural Areas, Nature Preserves, Range Reference Areas, or simply Natural Areas. They are tracts on which natural features are preserved in as nearly an undisturbed state as possible for scientific and educational purposes. Natural areas serve as a standard or baseline for comparison with areas influenced by man, as tracts for ecological and environmental study, and as reserves to protect typical as well as rare and endangered organisms. As baseline areas, field laboratories, and genetic reservoirs, they serve the scientist, the resource manager, and the public.

In the Pacific Northwest there has long been a steadily increasing interest in preserving typical and unique examples of the natural environment by the Federal Agencies, by the States of Oregon and Washington, and by various private groups and professional societies. However, a random accumulation of reserved tracts will not provide the representative system of Research Natural Areas needed. Coordination is required among the various groups to avoid unnecessary duplication and still preserve examples of all important terrestrial, freshwater, and marine ecosystems. Thus, one purpose of this guide.

Providing additional impetus to preparation of this guideline is the trend toward comprehensive land-use planning by Federal agencies and State and local government. I view the product as an important contribution to this planning process by alerting land planners to the value of Research Natural Areas and to the ecosystems lacking adequate representation in existing Research Natural Areas.

This guideline describes a minimal system of natural areas for Oregon and Washington. It is a working tool that will require revision as progress is made and as new information becomes available. This effort should not be viewed as a mandatory guide; it is a blueprint for coordination among the participants.

This guide was prepared under the overall direction of a steering committee whose members have long experience in administering programs involving renewable natural resources. More than 30 scientists made up the working group that prepared the basic plan, and several dozen reviewers offered valuable comment. However, the final responsibility for its adequacy rests with me and with the authors. We invite your comment and inquiry.

Robert E Buckman

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A very large number of people contributed to this report at one time or another. For example, over 100 people reviewed the manuscript and most made suggestions. Obviously, it is impossible to mention each by name, but we sincerely appreciate the effort expended by each reviewer.

Those who participated in the Natural Area Needs Workshop are recognized elsewhere in the report. Members of the steering committee and workshop participants are shown in appendix VII. However, many additional people made substantial contributions following the workshop during preparation of the review draft and this revised version of the report. In the following lists we will attempt to acknowledge these contributions. Because so many have been involved, it is, of course, likely that some who should be listed are inadvertently omitted. For this, we apologize.

Robert L. Fernald (University of Washington) organized a followup marine and estuarine workshop in November 1974, in order to improve lists of Research Natural Area needs along the coasts of Oregon and Washington. Those attending and making substantial contributions to the revised lists include Austin Pritchard, Vicki Osis, and Chris Bayne (Oregon State University); Laimons Osis (Oregon Fish Commission); and R. L. Bacon (University of Oregon). Other valuable suggestions were offered by J. J. Gonor, R. Waaland, R. Norris, T. Mumford, Peter Taylor, Peter Frank, Paul Rudy, R. T. Paine, and Carter Broad.

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Arthur Kruckeberg (University of Washington) and Jean Siddall (The Nature Conservancy), both workshop attendees, led the effort in compiling lists of plants of special interest in Oregon and Washington. Kenton Chambers (Oregon State University) shared data from his Oregon list of endangered plants, and C. Leo Hitchcock (University of Washington) was of major help in identifying special plants in Washington. Others who made contributions to the Oregon plant lists include Molly Grothaus, Frank McMullen, Lois Kemp, Ruth Hopson Keen, Bert Brehm, Calvin Burt, Russell Ofstadt, Ronald Burnett, Dorothy Marshall, Donald Kroeker, George Jeffcot, Lawrence Crocker, Frank Lang, Frank Secock, Roy Godfrey, Libby Pinkham, Diane Meyer, Ireta Kirkhofer, Jerry Strickler, Ruth Strong, and Ralph Anderson.

Glenn Juday wrote most of the section describing the Oregon State Natural Area Preserves Program. Information pertaining to the Washington State Natural Preserves Advisory Committee was supplied by A. R. O'Donnell and Gordon D. Alcorn.

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We sincerely appreciate the help and encouragement of all these people.

CONTENTS

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NATURE, PURPOSE, AND MANAGEMENT OF RESEARCH NATURAL AREAS

In this paper, we will generally follow the concepts of Research Natural Areas developed in the Federal program (Federal Committee on Research Natural Areas 1968). There are variations in what these natural ecological reserves are called and their specific rationale and management criteria. Nonetheless, the general objectives and criteria are common among, for example, the Federal, Oregon and Washington State, and The Nature Conservancy programs.

Research Natural Areas can be defined as "a naturally occurring physical or biological unit where natural conditions are maintained insofar as possible." Further, the natural features are preserved for research and educational purposes. The features to be preserved may be important or unique ecosystems, habitats, or organisms and may be terrestrial, freshwater, or marine.

Most tracts selected as Research Natural Areas are those where the features of interest are in as nearly an undisturbed state or natural condition as can be found. They do not necessarily have to be pristine, however, as examples of many ecosystems which are essentially free of human disturbance no longer exist. Research Natural Areas are, ideally, sufficiently large to protect the feature of interest from significant unnatural influences.

The objectives of establishing Research Natural Areas are critical to understanding their importance in overall land-use planning. As stated by the Federal Committee on Research Natural Areas (1968) they are: (1) preservation of examples of all significant natural ecosystems for comparison with those influenced by man; (2) provision of educational and research areas for ecological and environmental studies; and (3) preservation of gene pools for typical and rare and endangered plants and animals.

In both Federal and State Research Natural Areas, the overriding guideline for management is that natural processes are allowed to dominate to the degree consistent with preservation of the natural features of interest. On many Research Natural Areas, protection from outside disturbances, such as logging, grazing, and fire, is the only management requirement. However, deliberate manipulation which simulates natural processes is allowed and may be necessary in order to maintain desired communities or organisms. Prescribed burning or grazing by domestic livestock of some grassland types is an example. Use of Research Natural Areas for research or education must also be consistent with maintenance of natural processes and features. For this reason, only research which is nondestructive in character is generally allowed. Often research of this type can be complemented with manipulative research on adjacent experimental tracts. The Nature Conservancy management guidelines vary more with the nature of the preserve and the objectives for which it was set aside.

Recreation is not a recognized use of Research Natural Areas, although certain types of recreational activities are allowed if they do not significantly alter the natural features for which a given tract was set aside. If recreational or other human activities threaten the existence or natural development of the features, such use can and should be prohibited.

It is at this point we can see how Research Natural Areas relate to other land use classifications such as National Parks, Wilderness Areas, and the U.S. Forest Service's Botanical, Geological, etc., Areas. Research Natural Areas are for situations where scientific values are primary and, in fact, relatively stringent constraints on other uses are necessary for the protection and realization of these values. Of course, there remain many landscapes which have substantial scientific interest. This is certainly true of National Parks and Wilderness Areas which have unique scientific potentialities of certain types—e.g., groves of unusually large trees, rookeries, nesting sites for eagles, habitats for wide-ranging ungulates and predators. However, these are typically large tracts in which recreational, educational, and other values are equally as important as the scientific. Further, many of these particular scientific values can be protected concurrently with other uses or, at most, necessitate a restrictive scientific designation for only a small part of the total landscape of the Park or Wilderness.

Natural reserves of these less restrictive types are important scientifically and should be fully utilized. Indeed, they are essential if any reasonably complete examples of large landscapes and wide-ranging organisms (many birds and large herbivores) are to be preserved. They reduce the number and extent of needed Research Natural Areas but, at the same time, cannot replace their unique role. Often Research Natural Areas can be placed within National Park or Wilderness units, thereby identifying a specific site where research potential is high and providing it with an extensive buffer of undisturbed landscape.

To summarize, Research Natural Areas recognize scientific and educational values as primary. These values are also associated with National Parks, Wilderness, and other specially designated areas but typically do not require the more exclusive designation for their protection.

HISTORY OF RESEARCH NATURAL AREA PROGRAM IN OREGON AND WASHINGTON

There has been a high level of interest in establishment of Research Natural Areas in Oregon and Washington by many individuals and groups for many years. A short history of the various programs—Federal, State, and private—seems appropriate to provide some perspective for this report.

Federal Activities

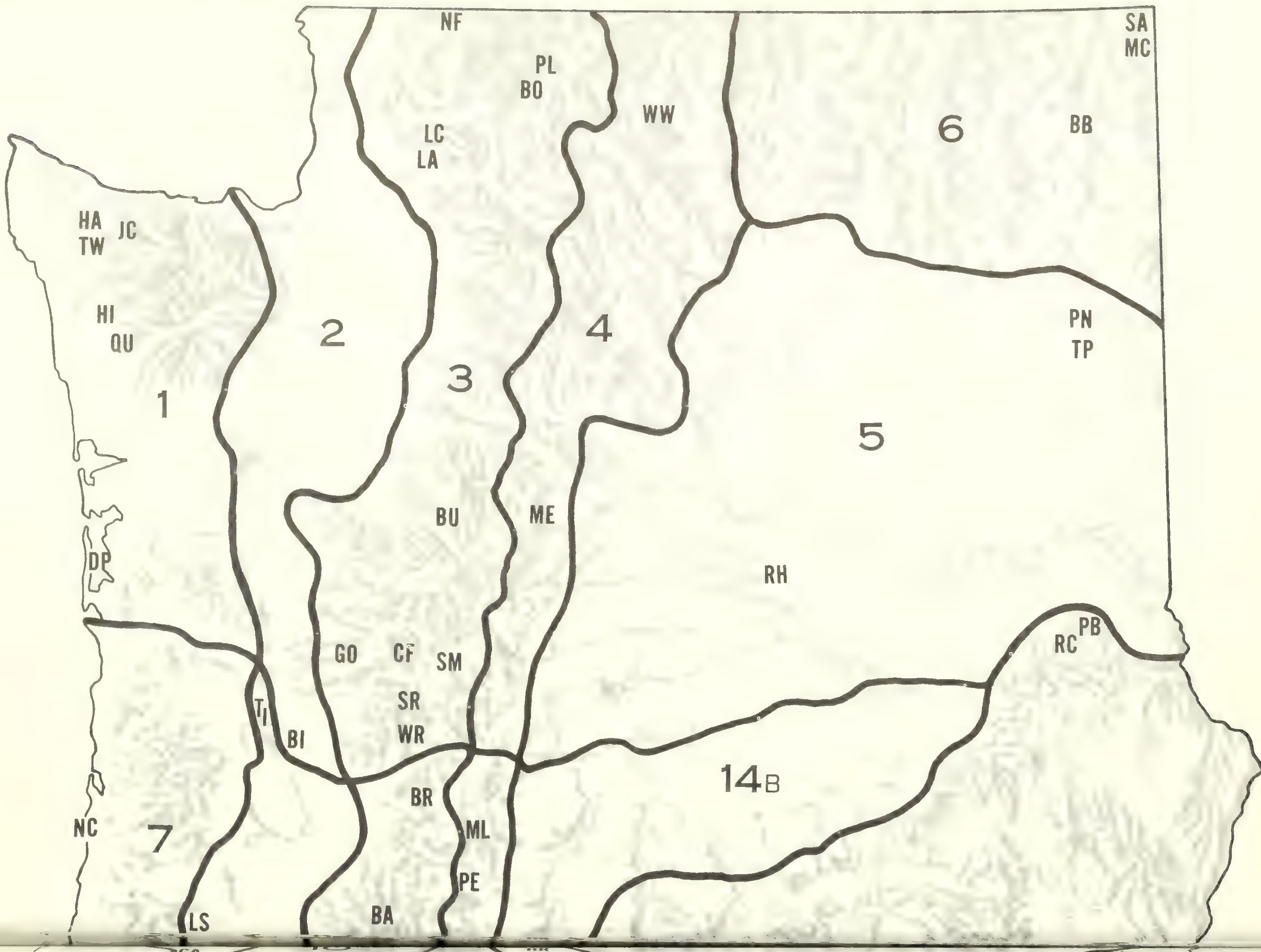
The Federal agencies have been active in the selection and dedication of Research Natural Areas for the longest period of time. Personnel in the U.S. Forest Service's Pacific Northwest Forest and Range Experiment Station were among the early activists—Thornton T. Munger, Leo A. Isaac, and Philip Briegleb, for example. The first of now 60 Federal Research Natural Areas in Oregon and Washington was formally established in 1931 by the U.S. Forest Service (Franklin 1970, Franklin et al. 1972). Over the next 30 years, location and establishment of areas proceeded at a slow but steady pace, with other Federal agencies becoming involved, including the Bureau of Land Management, National Park Service, and Fish and Wildlife Service.

In the 1960's, Federal agencies expanded and coordinated their activities. On the national level this was accomplished through the establishment of the Federal Committee on Research Natural Areas at the joint initiative of the Secretaries of Interior and Agriculture. Regionally, it took the form of increased interchange among the agencies. The Pacific Northwest Research Natural Area Committee, originally exclusively Forest Service, became interagency with representation of the Bureau of Land Management, Fish and Wildlife Service, and the National Park Service, as well as The Nature Conservancy. Their earliest cooperative efforts culminated in a guidebook to the then-existing 48 Federal Research Natural Areas (Franklin et al. 1972). Since 1972 the four Federal agencies have pooled financial resources to support a summer activities program (identifying, describing, and conducting research on natural areas) and have joined, of course, in sponsoring this report and the workshop upon which it is based.

There are, at present, 60 Federal Research Natural Areas in Oregon and Washington (fig. 1, table 1) and a number of additional areas being either considered or established (app. I).

Two aspects of the Federal program have evolved along with the improved coordination and the expansion of the system. The Forest Service involvement in the program was based initially upon the need for a system of areas which provided representative examples of the important forest and range types. All early Forest Service Research Natural Areas were of this type. In the middle 1960's, the concept was broadened to include all types of ecosystems, either typical or unique, aquatic as well as terrestrial. This broader concept has guided the entire Federal program since that time.

Secondly, the Federal agencies have continually endeavored to improve the systematic basis or general plan for the program. The plan developed here is, in fact, the latest in a series which have successively approximated the total scope of a system of reserves and remaining needs, each reflecting an improved understanding of the ecology of the region, future research needs, and the objectives of the system.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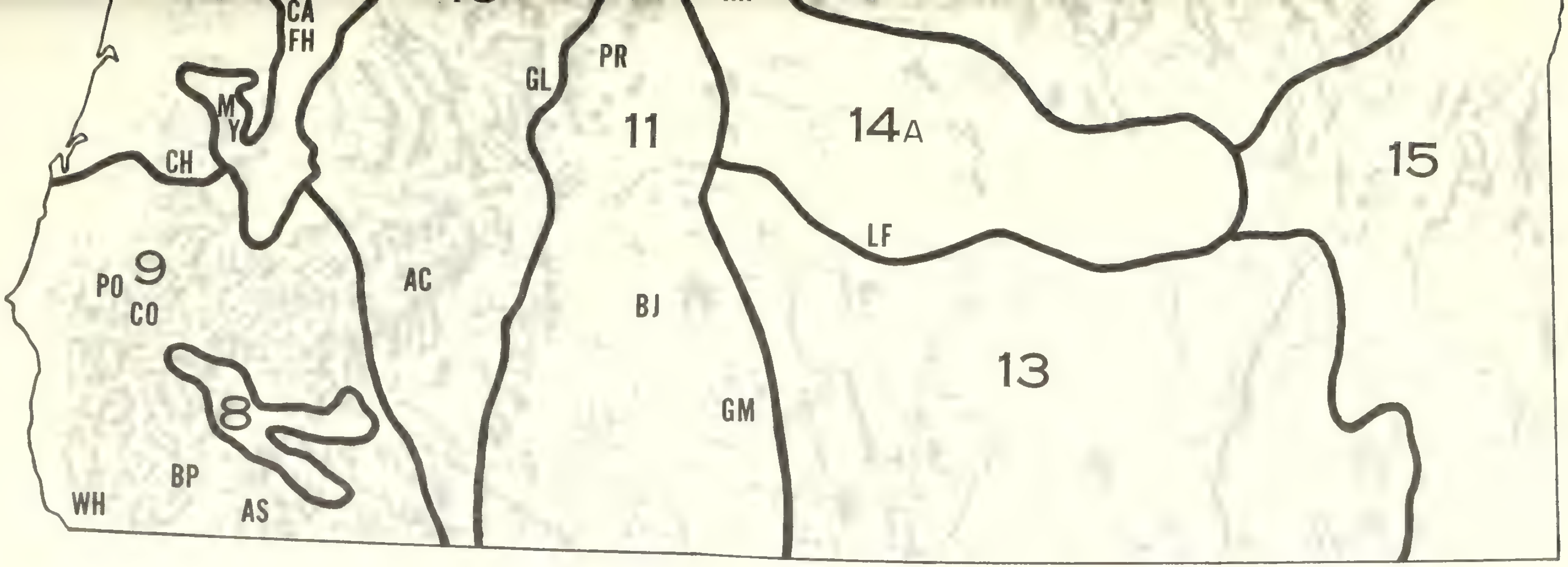


Figure 1.--Physiographic provinces and established Federal Research Natural Areas in Washington and Oregon. (See table 1, pages 6-8, for letter code for specific Research Natural Area.)

NO.	PROVINCE	NO.	PROVINCE
1	Olympic Peninsula and Southwestern Washington	9	Siskiyou Mountains
2	Puget Trough	10	Western Slopes and Crest, Oregon Cascades
3	Western Slopes and Crest, Washington Cascades	11	Eastern Slopes, Oregon Cascades
4	Eastern Slopes, Washington Cascades	12	Ochoco, Blue, and Wallowa Mountains
5	Columbia Basin	13	Basin and Range
6	Okanogan Highlands	14	High Lava Plains and Columbia Basin
7	Oregon Coast Ranges		A - High Lava Plains
			B - Columbia Basin
8	Western Oregon Interior Valleys	15	Owyhee Upland

Table 1.--*Established Federal Research Natural Areas in Oregon and Washington*

Code	Name	Principal features	Administering agency[1]	Area	
				Ha	A
AC	Abbott Creek	Sierran-type mixed conifer forest	FS	1 077	2
AS	Ashland	"Pacific" ponderosa pine, pure or mixed with Douglas-fir	FS	570	1
BA	Bagby	Douglas-fir-western hemlock forests	FS	227	
BB	Baird Basin	Interior ponderosa pine, larch, and Douglas-fir	FWS	65	
BI	Blackwater Island	Oregon white oak-Douglas-fir grassland on uplands, and willow, Oregon ash in lower portions, of channeled basalt along Columbia River	FWS	52	
BJ	Bluejay	Ponderosa and lodgepole pine on coarse pumice	FS	85	
BO	Boston Glacier	Major alpine glacier and cirque on northern Cascade Range including some recently deglaciated topography	NPS	1 061	2
BP	Brewer Spruce	Brewer spruce with many other conifers	BLM	85	
BR	Bull Run	Noble and Pacific silver firs and western hemlock	FS	146	
BU	Butter Creek	Subalpine mosaic of forest, meadow, and shrub communities with lakes and ponds	NPS	810	[illegible]
CA	Camas Swale	Dry Douglas-fir forest in foothills of Willamette Valley	BLM	130	
CC	Canyon Creek	Interior ponderosa pine forest	FS	283	
CF	Cedar Flats	Western redcedar and associated swamps and marshes and Douglas-fir forest	FS	275	
CH	Cherry Creek	Coast Ranges Douglas-fir forest	BLM	239	
CO	Coquille River Falls	Port-Orford-cedar stands	FS	202	
DP	Diamond Point	Sitka spruce-western hemlock forest	FWS	36	
FH	Fox Hollow	Dry Douglas-fir-ponderosa pine forest in foothills of Willamette Valley	BLM	51	
GO	Goat Marsh	Extensive mountain marshes, record noble fir forest, beaver swamp, ponds, and lodgepole pine on recent mudflow	FS	484	
GL	Gold Lake Bog	Subalpine bog communities and flora	FS	188	
GM	Goodlow Mountain	Interior ponderosa pine forest	FS	510	
HA	Hades Creek	Low-elevation Pacific silver fir-western hemlock forests	NPS	227	
HI	Higley Creek	Western hemlock forests	NPS	194	
HR	Horse Ridge	Western juniper savanna	BLM	243	

See footnote at end of table.

Table 1.--*Established Federal Research Natural Areas in Oregon and Washington* (Continued)

Code	Name	Principal features	Administering agency[1]	Area	
				Ha	Acres
JC	Jackson Creek	Douglas-fir forest	NPS	65	160
LA	Lake Twentytwo	Western redcedar-western hemlock forests and subalpine lake	FS	320	790
LS	Little Sink	Slump ponds and conifer-bigleaf maple forest on margin of Willamette Valley	BLM	32	80
LC	Long Creek	Western hemlock forests	FS	259	640
LF	Lost Forest	Isolated ponderosa pine stands and sand dunes within a low-rainfall, shrub-steppe region in central Oregon	BLM	3 628	8,960
MC	Maitlen Creek	Douglas-fir/ninebark forest with stream drainage	FS	259	640
MA	Maple Knoll	Bigleaf maple stands	FWS	40	100
ME	Meeks Table	Interior ponderosa pine forests on isolated butte	FS	28	68
MI	Metolius	Interior ponderosa pine forests	FS	583	1,440
ML	Mill Creek	Mosaic of interior mixed-conifer and Oregon white oak forest, and grass and shrub steppe	FS	330	815
MO	Mohawk	Douglas-fir, western hemlock, and western redcedar forest in foothills along Willamette Valley	BLM	61	150
MY	Myrtle Island	California laurel stands	BLM	11	28
NC	Neskowin Crest	Sitka spruce-western hemlock forests	FS	278	686
NF	North Fork Nooksack	Douglas-fir and western hemlock forests	FS	605	1,495
OD	Ochoco Divide	Ponderosa pine-Douglas-fir and grand fir-western larch-Douglas-fir forests	FS	777	1,920
OR	Olallie Ridge	Subalpine mountain meadows with rich flora and mixed conifer forests	FS	291	720
PB	Pataha Bunchgrass	Bluebunch wheatgrass stands	FS	21	51
PE	Persia M. Robinson	Douglas-fir and ponderosa pine forests	FS	219	540
PI	Pigeon Butte	Oregon white oak stands	FWS	28	70
PN	Pine Creek	Interior ponderosa pine and grasslands	FWS	65	160
PO	Port Orford Cedar	Port-Orford-cedar and Douglas-fir forests	FS	454	1,122
PR	Pringle Falls	Lodgepole and ponderosa pine forests on coarse pumice	FS	470	1,160

See footnote at end of table.

Table 1.--*Established Federal Research Natural Areas in Oregon and Washington* (Continued)

Code	Name	Principal features	Administering agency[1]	Area Ha	Area Acres
PL	Pyramid Lake	Subalpine lake with surrounding conifer forest	NPS	48	119
QU	Quinault	Western hemlock-Sitka spruce forests	FS	594	1,468
RC	Rainbow Creek	Interior mixed-conifer forest with abundant western white pine	FS	170	420
RH	Rattlesnake Hills	Dry Columbia Basin shrub steppe	ERDA	30 364	75,000
SA	Salmo	Interior subalpine fir and western hemlock-western redcedar forest with stream drainage	FS	563	1,390
SR	Sister Rocks	Pacific silver fir forests	FS	87	215
SM	Steamboat Mountain	Subalpine fir, Pacific silver fir and mountain hemlock forest, pond, and marshes	FS	567	1,400
TI	Tenasillahe Island	Black cottonwood-willow island stand in lower Columbia River	FWS	75	185
TP	Turnbull Pine	Interior ponderosa pine stands, grasslands, and ponds	FWS	81	200
TW	Twin Creek	Sitka spruce stands of "rain forest" type	NPS	40	100
WH	Wheeler Creek	Redwood-Douglas-fir forests near the northern limits of redwood	FS	135	334
WM	Wildcat Mountain	Noble fir, Pacific silver fir, and mountain hemlock forests associated with meadow and shrub communities	FS	405	1,000
WP	Willamette Floodplain	Willamette Valley bottomland grass and Oregon ash communities	FWS	97	239
WR	Wind River	Douglas-fir-western hemlock forests	FS	478	1,180
WW	Wolf Creek	Bitterbrush and bunchgrass communities	FS	61	150

[1] BLM = Bureau of Land Management
ERDA = Energy Research and Development Administration
FS = Forest Service
FWS = Fish and Wildlife Service (National Wildlife Refuges)
NPS = National Park Service.

The State of Washington

In January 1966, the Intercampus Committee for Educational and Scientific Preserves (ICESP) met at Central Washington State College to discuss the development of a statewide Natural Area Preserve system. From 1967 to 1970, with modest funding available, inventories of actual and potential natural areas were prepared by a number of individuals from Western Washington State College, University of Washington, and Washington State University. The inventories of State and private lands received cooperation from the State of Washington Department of Natural Resources. During this period, Wallace Heath, Chairman of the ICESP, helped to keep the idea of a Natural Area Preserve system viable, and he secured some interim funding. The 1970 Session of the State Legislature passed Senate Bill 360, a proposal within the multiple-purpose act for the Department of Natural Resources; it authorized the withdrawal of certain lands under State ownership for scientific and educational purposes. In the fall of 1971, Representative Lois North was approached with the concept of a statewide Natural Area Preserve system; Representative North secured a hearing on the subject by the Interim Legislature Council in December 1971, and reaction was favorable. A bill to create a Natural Area Preserve system was introduced into the State legislature in January 1972 (see appendix III for the complete text of this act); it was signed into law in February, at which time the Washington State Natural Preserves Advisory Committee was established with Gordon Alcorn of the University of Puget Sound as chairman. The Advisory Committee, consisting of seven voting members, is charged with reviewing prospective natural areas and with making recommendations to the Department of Natural Resources.

Natural areas are envisioned as permanent entities, and provisions have been made to ensure maximum protection. As such, their intended value embraces both educational and scientific interests. They allow continuing, nondestructive baseline studies, protection of endangered species, and, as "living museums," enhance the intrinsic cultural values, scenic beauty, and man's relationship to his environment.

Progress to date is as follows:

Natural preserve	*County*	*Status*	*Key feature*	*Size*	
				Ha	*Acres*
Sand Island and Goose Island	Grays Harbor	Established	Caspian tern rookery	10	25
Protection Island	Jefferson, off Point Discovery, Strait of Juan de Fuca	Established	Rhinoceros auklet rookery	15	36
Mima Mounds	Thurston	Being negotiated for long-term lease from The Nature Conservancy	Mima mounds	283	700

The State of Oregon

The State of Oregon became formally involved in setting aside natural areas in 1973 with the passage of the Oregon Natural Area Preserves Act (see app. IV for the complete text of this act). Glenn Patrick Juday, an Oregon State University graduate student, drafted most of the legislation and played a significant role in the passage of the act. The State Natural Area

Preserves Advisory Committee, authorized by the legislation and consisting of seven voting members, was appointed November 21, 1973, with Juday as chairman. This committee secures information, coordinates the State's efforts in natural area preservation, and makes recommendations to the State Land Board (comprised of the Governor, Secretary of State, and State Treasurer) concerning establishment of specific preserves. The authority to establish preserves is vested in the State Land Board. The Natural Area Preserves Act stipulates that State Preserves are established for scientific and educational benefits, as well as to encourage the appreciation of natural features.

The establishment procedure is a formalized rulemaking process that provides statutory protection from undue disturbance which would jeopardize a preserve's scientific and educational values. In addition to aiding in the establishment of preserves, the Advisory Committee is charged with surveying the State in order to create and maintain a registry of areas which may be suitable for inclusion within preserves. The Act provides that all areas included as preserves must be public lands. The committee is reviewing State Forest, State Park, Wildlife, and Board of Higher Education lands. According to the legislation, county and city parks, forests, and recreation lands may also qualify as Natural Area Preserves. Although no preserves have, as yet, been established, because of an excellent State Park acquisition history and generally progressive management by the State Forest system and the Wildlife Commission, a number of outstanding candidate areas are still available.

The Advisory Committee has, to date, concentrated on internal organization, establishing working relationships with the many individuals and agencies involved in natural area work, and establishing the procedure by which preserves are dedicated. It is expected that once these tasks are completed, the actual dedication of areas can proceed efficiently and rapidly.

The Nature Conservancy

The Nature Conservancy has a long historical involvement in preservation of Research Natural Areas. It began with the establishment of the Natural Areas Committee of the Ecological Society of America in 1917. This group, formed to take inventory of the remaining natural areas in North America became The Ecologists Union in 1946 and The Nature Conservancy in 1951. Its concerns have typically included Research Natural Areas, as defined in this document, but have also been somewhat broader, including preservation of land for other than strictly scientific and educational purposes. The Nature Conservancy has an active program of land acquisition by donation and purchase, as well as either managing these areas or tranferring lands to other agencies to insure their continued protection. Nationally, The Nature Conservancy has preserved over 600,000 acres (242 915 hectares) of land in over 1,100 preserves.

A substantial portion of The Nature Conservancy's programs is handled through local chapters and with volunteer labor. In Washington and Oregon three chapters have been chartered—the Western Washington, Inland Empire, and Oregon Chapters. In addition, a northwest office has been established to provide assistance to the chapters as well as liaison with the western regional and national offices.

Since establishment of the first preserve in the Pacific Northwest in 1962, 16 areas have been preserved (table 2). To establish priorities for natural area preservation, the Oregon Chapter has undertaken an Oregon inventory of natural areas on private lands (The Nature Conservancy 1974), an effort coordinated with State and Federal programs of natural area preservation. The Nature Conservancy is also involved in an inventory of natural areas in San Juan County, Washington.

In order to utilize inventory data and select priorities for natural area preservation activities, The Nature Conservancy has felt the need for an overall plan in which the needs, as well as their role relative to other groups, are defined; hence, its involvement in the planning activity reported in this document.

Table 2.--*The Nature Conservancy Preserves established or in process of establishment in Oregon and Washington*[1]

Name	Principal features	Size Ha	Size Acres
Anderson Lake State Park Natural Area	Outdoor recreation area associated with State park in western Washington	6	15
Burnt Bridge Creek Natural Area	Freshwater marsh with marginal oak, maple, and Douglas-fir forests near Vancouver Lake in southwestern Washington; to be associated with natural recreational park	5	12
Camassia Natural Area	Oak, madrone, camas, and aspen associated with openings and rock gardens floristically rich and with numerous ponds on basalt bluffs above the lower Willamette River, Oregon; leased to Lewis and Clark College	9	23
Cascade Head Preserve	Oregon coastal headland with extensive grassland and conifer and red alder forest	121	300
Cogswell-Foster Preserve	Oregon white oak and Oregon ash woodlands and seminatural grasslands in central Willamette Valley, Oregon	34	83
Dickey River	Virgin coniferous forest on the west slopes of the Olympic Peninsula in Washington	2	6
Dishman Hills Natural Area	Part of 640-acre tract of ponderosa pine and Douglas-fir near Spokane, Washington, used for hiking and nature study	.32	80
Englehorn Pond Preserve	Pond and cattail marsh surrounded by low woods on edge of Columbia Basin in Ellensburg, Washington	1	2
Foulweather Bluff Preserve	Project to preserve waterfront and mixed conifer-hardwood forest along Hood Canal and a freshwater marsh on the eastern edge of the Olympic Peninsula in Washington	40	100
Lake Louise Ecological Preserve	Access tract to ecologically rich pond on an 80-acre Western Washington State College educational site	2	4

See footnote at end of table.

Table 2.--*The Nature Conservancy Preserves established or in process of establishment in Oregon and Washington*[1] (Continued)

Name	Principal features	Size Ha	Size Acres
Lawrence Memorial Grasslands Preserve	Bluegrass-bunchgrass community (steppe) on biscuit scabland near Shaniko, Wasco County, eastern Oregon	153	378
Mima Mounds Research Natural Area	Mima mound phenomenon and associated vegetation near Olympia, Washington; area leased from Washington State Department of Natural Resources through The Nature Conservancy to Evergreen State College	222	548
Moxee Bog Preserve	Floating sphagnum bog with rare butterfly colony in steppe region of Yakima County, Washington; managed by Yakima Community College	6	14
Neahkanie Beach Natural Area	Rushes and grasses on strand and willows on stabilized dunes along northern Oregon coast	1	2
Protection Island	Rhinoceros auklet breeding ground and seal haul out off Point Discovery, Strait of Juan de Fuca. Managed by Washington State Department of Game	15	36
Rose Creek Preserve	Seminatural grassland and shrub communities in Palouse region of southeastern Washington; being restored	5	12
Sandy River Gorge Preserve	Project to acquire portions of river gorge and associated river bar and canyon wall forests, lower Sandy River in western Oregon near Portland	77	190
Waldron Island	Project to acquire beach, large marsh, and Douglas-fir-hardwood forests in San Juan Island group, Puget Sound, Washington; cooperating with San Juan Island Conservation Committee	104	256
Wildflower Acres Natural Area	Wooded area in urban Puget Sound environment, Snohomish County, Washington; conveyed to Western Washington State College	10	25

[1] Not all these areas qualify as Research Natural Areas in the sense of primary or exclusive dedication to scientific use.

Professional Societies

A number of professional societies, most notably the Society of American Foresters and the Society for Range Management, have encouraged preservation of Research Natural Areas in the Pacific Northwest. For a perspective on these programs, which do not involve actual acquisition of lands, see Romancier (1974).

DEVELOPMENT OF THE SYSTEM OUTLINE

The need for developing an overall Research Natural Area plan for Oregon and Washington is obvious. Suitable areas are rapidly being converted to other uses, reducing options for preserving examples of specific organisms and natural ecosystems—permanently in some cases. The profusion of individuals, agencies, and institutions actively involved suggests possible duplication of effort with consequent inefficiencies and confusion in the minds of the public as well as the land managers and politicians who must respond to the numerous proposals and initiatives. Comprehensive land planning by several major Federal land management agencies as well as by State and local governments makes the comprehensive outline of the ecosystems and organisms of critical scientific interest particularly important. Land managers and planners, as well as other interested public and private groups, need to know the scope and content of a minimal scientific preserve system, that it is finite, and that the diverse activities are coordinated.

In 1972 and early 1973, each major group involved in Research Natural Area programs concluded, almost simultaneously, that it needed a plan to guide its activities, including a listing of ecosystems and organisms of interest and a priority ranking for consideration. At the Federal level, this was reflected in a determination by the Pacific Northwest Research Natural Area Committee to prepare a new list of natural area needs to guide Federal land planners. In the States of Washington and Oregon, the Natural Area Advisory Committees established under recent legislation were charged with developing master plans outlining the scope and content of the system. The Nature Conservancy also wanted a long-range plan for its activities.

Aware of their similar and overlapping needs, these four groups agreed to join in a common effort to develop a comprehensive outline for an Oregon-Washington Research Natural Area system under the leadership of Robert E. Buckman, Chairman of the Pacific Northwest Research Natural Area Committee, the focal point for Federal agency activity in this region. As the initial step, a workshop was held in late November of 1973 to develop an outline of a minimal Research Natural Area system for the Pacific Northwest which would also identify the roles of each agency and institution involved in establishing such preserves.

Workshop Format and Charge

The workshop was planned and charged with its tasks by the Steering Committee, organized and headed by Dr. Buckman. Steering Committee members were primarily State and Federal agency heads charged with significant administrative responsibilities:

Robert E. Buckman, Director, Pacific Northwest Forest and Range Experiment Station, U.S. Forest Service
Kessler R. Cannon, Governor's Assistant for Natural Resources (Oregon)
Archie D. Craft, State Director, U.S. Bureau of Land Management
Don Lee Fraser, Supervisor, Natural Resources, Washington Department of Natural Resources

Arthur R. Kruckeberg, Chairman, Washington Intercampus Committee on Educational and Scientific Preserves
Kenneth R. Margolis, Northwest Representative, The Nature Conservancy
R. Kahler Martinson, Regional Director, U.S. Fish and Wildlife Service
John A. Rutter, Regional Director, National Park Service
Theodore A. Schlapfer, Regional Forester, U.S. Forest Service
Phillip W. Schneider, Regional Executive, National Wildlife Federation

Attendance at the workshop was limited to keep the group of a workable size (see list of participants in app. VII); consequently, all interested and concerned scientists and other individuals could not be invited. Nevertheless, it was essential that participants representing the various relevant scientific disciplines (for example, geology, soils, limnology, and marine biology), as well as the major institutions and agencies involved in the Research Natural Area programs, be present. It was viewed as particularly important to have both scientists and land managers present because any plan needed to be jointly developed and mutually acceptable—those who could best identify the needs and would use the area should join in planning with those aware of the constraints and possibilities and who would set up and administer such tracts.

Workshop participants were charged with identifying the elements of a minimal Research Natural Area system for Oregon and Washington. In other words, what kinds of ecosystems and numbers of each should be protected by a Federal, State, or private institution within scientific reserves? The steering committee, in turn, reviewed the product of the workshop for its overall soundness and acceptability.

To meet this overall objective, six tasks were identified for the workshop participants:

1. Identify the terrestrial ecosystems which should be represented in the various physiographic provinces;
2. Identify the freshwater ecosystems which should be represented in the various physiographic provinces;
3. Identify the marine ecosystems, including estuarine, that should be represented;
4. Review rare and endangered plant and animal species and identify and list those best handled in a Research Natural Area context;
5. Match the four lists of needs against features already preserved in Research Natural Areas to identify remaining needs; and
6. Rank the remaining needs as to priority for attention and identify a lead agency or organization for each of the remaining needs (the group most likely to be able to fill the need).

To accomplish these tasks the participants were divided into five working groups based on their expertise: terrestrial ecosystems west of the Cascade Range, terrestrial ecosystems east of the Cascade Range, freshwater ecosystems, marine and estuarine ecosystems, and rare and endangered organisms.

Some additional guiding principles were provided:

1. The system should include examples of typical ecosystems as well as those which are unique or unusual.
2. Areas, features, and organisms having some scientific interest are practically infinite and only those cases requiring a special designation to protect the scientific values and enhance research potential should be identified as Research Natural Area needs. Scientific and educational values of an area can often be protected by other means. A species of plant or animal can be protected, sometimes more adequately, without requiring a Research Natural Area. Since land is a limited commodity with many competing uses, the Research Natural Area designation should be used only where it is essential.

3. Number of required areas for a given ecosystem should vary with its importance and variability. For example, where a particularly important system, such as Douglas-fir forest, is involved, sufficient examples should be proposed to encompass the major mixtures, environments, and ages. Furthermore, their importance should be considered in the context of whether the variations are sufficient to result in major differences in ecosystem function (e.g., growth) and to have different land management implications.

Operation of the Workshop

The findings of the working groups and overall plan for the system are presented in later sections; however, it might be helpful to indicate how the effort evolved. At the outset the five working groups differed markedly in their starting point. The terrestrial groups and, to a lesser extent, the aquatic (freshwater) group had preliminary lists from which to work. Working groups on marine ecosystems and rare and endangered organisms had no listings or classifications relevant to planning scientific reserves.

Primary attention evolved toward the listing of cells—ecosystems or organisms which needed to be represented—as these are the basic subject units in developing a system. Various geographic or physiographic provinces were, in the case of terrestrial and aquatic systems, used as the basic stratification; and cellular listings were developed for each province. The cells differed in the degree to which they were defined, depending largely upon the level of knowledge about that ecosystem.

It became clear early in the deliberations of the working groups that a number of the cells could reasonably be expected to occur together and, hence, might possibly be combined into a single Research Natural Area. In the terrestrial and aquatic (freshwater) groups this process of aggregation advanced almost simultaneously with the listing of cells. In this way, the probable number of needed areas and their desired composition with regard to cells were developed together. Listings of cells in the marine and rare and endangered groups proceeded in a somewhat different fashion (see the reports of these working groups); ultimately rare and endangered cells for some animals were identified and incorporated into the list of needed Research Natural Areas.

The Cellular Approach To Developing Research Natural Area Needs

Before proceeding with the report, it is important that the reader have some concepts firmly in mind. Cells are the basic units which must be represented in a natural area system. A cell can be an ecosystem, community, habitat, or organism. Organisms are generally recognized implicitly in cells identified for ecosystems, communities, or habitats. However, where an organism is of particular scientific significance or is rare or threatened, it may receive explicit recognition as a cell.

A "Research Natural Area need," as identified in this report, is typically an aggregation of several cells which need representation. This, of course, assumes that these cells can be found together. The listed "needs" are simply guides intended mainly to encourage, insofar as possible, the establishment of multicellular Research Natural Areas. It may or may not prove possible to find a "Research Natural Area need" with the described aggregation of cells when a site is actually sought in the field. In all cases it must be remembered that it is the individual cell which is the basic unit requiring representation.

Part II. Research Natural Area Needs by Province

Outlined in this section are the major elements proposed for a comprehensive Research Natural Area system. It is based upon the best judgments of many individuals in universities and State and Federal agencies as well as the private sector. The plan should not be considered as either final or complete; it is a starting point and will be periodically revised. As the system develops and our knowledge of natural ecosystems increases, we should expect the type and number of areas needed to evolve through improved definition of needs, additions, and deletions. The potential role and needs for Research Natural Areas in marine ecosystems and for rare and endangered organisms are, perhaps, most poorly understood.

Nonetheless, it is clear what the overall scope of a minimal Research Natural Area system must be. The numbers of desired cells are summarized by physiographic province in table 3 for terrestrial and aquatic (freshwater) ecosystems and total approximately 360 and 180, respectively. Cells for rare and endangered vertebrate animals total 94. Substantial progress has already been achieved in representing examples of terrestrial cells (approximately 25 percent complete); however, existing Research Natural Areas have served aquatic needs much more inadequately (approximately 10 percent of cells are filled). Existing Research Natural Areas are known to fill only seven of the rare and endangered animal cells. Vascular plants of special interest were not identified as cells; a few are present on existing Research Natural Areas but our knowledge of the flora of many reserves is quite poor.

Table 3.--*Number of terrestrial, aquatic, and rare and endangered animal cells or ecosystems needing representation in Research Natural Areas in Oregon and Washington and number already filled or represented in existing reserves*

Province	Terrestrial cells		Aquatic (freshwater) cells		Rare and endangered animal cells	
	Total	Filled	Total	Filled	Total	Filled
Olympic Peninsula and Southwestern Washington	27	8	17	0	4	0
Puget Trough	16	2	8	1	4	0
Western Slopes and Crest, Washington Cascades	31	16	18	7	8	0
Eastern Slopes, Washington Cascades	21	4	11	0	7	0
Columbia Basin, Washington	43	7	13	2	12	3
Okanogan Highlands	27	5	11	2	3	0
Oregon Coast Ranges	23	5	13	0	4	1
Western Oregon Interior Valleys	26	8	9	1	6	0
Siskiyou Mountains	26	7	14	2	8	2
Western Slopes and Crest, Oregon Cascades	27	7	17	3	7	1
Eastern Slopes, Oregon Cascades	17	9	8	0	2	0
Ochoco, Blue, and Wallowa Mountains	25	6	13	0	5	0
Basin and Range	19	0	14	0	10	0
High Lava Plains and Columbia Basin, Oregon	19	8	6	0	8	0
Owyhee Upland	15	0	8	0	6	0
Total	362	92	180	18	94	7

Although the identification of marine and estuarine cells is not as complete, this working group recommended the establishment of 68 Research Natural Areas in coastal environments. If we assume that each natural area will fill, on the average, two cells, our estimate of total marine and estuarine cells amounts to approximately 172.

Putting all these cells or basic planning components together, we arrive at a Research Natural Area (RNA) system which should incorporate about 772 ecosystems, habitats, or rare and endangered organisms:

Terrestrial cells	362
Aquatic (freshwater) cells	180
Rare and endangered animal cells	94
Marine and estuarine cells[1]	136
Total	772

Of course, this in no way implies a need for that many Research Natural Areas. In fact, it is estimated that the actual number of Research Natural Areas needed to provide examples of the various ecosystems is considerably less than half, or about 360. This is because areas can logically be selected which will fill several cells (terrestrial, aquatic, and rare and endangered) simultaneously. Experience to date with the 60 established Federal Research Natural Areas (see table 1) indicates an average of around two filled cells per area even though most were selected to represent a single cell. One (Rattlesnake Hills RNA) fills at least 10 cells needed in the Columbia Basin.

Research Natural Area needs were identified on a province-by-province basis (fig. 1), following a common format which incorporates most of the relevant information for each. The province presentation begins with a brief description of the physical and biologic features encountered. The cells which should be represented in a minimal natural area system are listed and described for terrestrial and aquatic (freshwater) ecosystems and rare or endangered vertebrate animals. Vascular plants of special interest are briefly discussed and listed. These necessary cells or components in the province are then compared with existing Research Natural Areas to determine cells which remain to be filled.

The last table in each province presentation identifies the type and number of additional Research Natural Areas which will probably be required to provide minimal coverage of the remaining unfilled cells. This has been done by aggregating the unfilled cells which could, with reasonable likelihood, be found within a single area and listing these as needed Research Natural Areas. In other words, the unfilled cells have been aggregated into *tentative* units listed as Research Natural Area needs.

The proposed Research Natural Area needs can be summarized as follows:

Terrestrial-aquatic (freshwater) RNA's	46
Terrestrial RNA's	125
Aquatic (freshwater) RNA's	64
Special interest plant and animal RNA's	13
Marine and estuarine RNA's (tentative)	68
Total additional RNA's	316
Existing RNA's	60
Total RNA's in proposed system	376

Research Natural Area needs are summarized by State and physiographic province in table 4.

[1] We have not attempted to define marine and estuarine cells but rather specific areas needed as RNA's. Therefore, this is only a very rough estimate of number of needed cells.

Table 4.--*Estimated number of Research Natural Areas needed by State and physiographic province*
(Does not include marine and estuarine needs)

State and Province	Terrestrial and aquatic (freshwater) RNA's	Terrestrial RNA's	Aquatic (freshwater) RNA's	RNA's for rare and endangered species	Total
ington:					
ympic Penninsula and Southwestern Washington	6	9	6	1	22
get Trough	0	11	6	0	17
stern Slopes and Crest, Washington Cascades	3	9	6	3	21
stern Slopes, Washington Cascades	3	11	4	3	21
lumbia Basin, Washington	0	9	3	0	12
anogan Highlands	3	9	1	0	13
Total	15	58	26	7	106
gon:					
egon Coast Ranges	6	5	4	0	15
stern Oregon Interior Valleys	1	14	6	1	22
skiyou Mountains	5	10	6	3	24
stern Slopes and Crest, Oregon Cascades	5	13	4	0	22
stern Slopes, Oregon Cascades	3	6	4	1	14
hoco, Blue, and Wallowa Mountains	5	9	4	0	18
sin and Range	4	2	4	0	10
gh Lava Plains and Columbia Basin, Oregon	0	4	5	0	9
yhee Upland	2	4	1	1	8
Total	31	67	38	6	142
otal, both States	46	125	64	13	248

A final reminder to users of these lists:

(1) Lists are not "final" but will undoubtedly be adjusted in future years. They do provide a basic outline for identifying candidate Research Natural Areas as a part of comprehensive land use planning.

(2) Cells are the basic units requiring representation and the focus is on filling these. The Research Natural Area needs listed are our best estimate as to how this can be done with the greatest economy in number and size of areas required.

(3) Scientists from several disciplines will be necessary in selecting areas to fill several cells.

(4) The listing of multicell Research Natural Areas should not lead to excessive pursuit of an ideal area. If an area with all attributes listed cannot be found after a reasonable search, the need as listed here should be broken down into two or more Research Natural Area needs which cover the same cells.

(5) Most of the needed Research Natural Areas are common or typical ecosystems rather than unique or unusual types. These should be as representative as possible of the normal environments (geology, climate, soils, etc.) occupied by those ecosystems. Representativeness is extremely important if Research Natural Areas are to be used as baseline or control areas for managed lands and as sites for research with management relevance.

(6) Size of desired areas will vary widely and is determined by the nature of the ecosystem or organism we wish to preserve.

OLYMPIC PENINSULA AND SOUTHWESTERN WASHINGTON PROVINCE

The Olympic Peninsula is made up of a central core of the rugged Olympic Mountains surrounded by almost level lowlands (fig. 1). The effects of glaciation and rapid stream dissection due to the extremely heavy precipitation have combined to produce precipitous mountain slopes. All river valleys draining the Olympic Mountains are broad and U-shaped; and all major peaks are ringed with cirques, many containing active glaciers.

Geologically, the central portion of the Olympic Mountains is made up of late Mesozoic graywacke, with some interbedded slate, argillite, and volcanic rocks. This interior portion is encircled on the north, east, and south by two belts of volcanic rocks (largely basalt and flow breccia). The broad, level areas along the western and southern margins of the peninsula have been interpreted as marine terraces or glacial outwash fans.

Forested soils formed on the sedimentary rocks of the interior of the Olympic Mountains have been reported to be Brown Podzolics, with silt loam surface horizons and sandy clay loam B horizons. On the more gentle slopes, basalt parent materials give rise to deep, well-developed reddish-brown soils, generally of silty clay loam texture. Soils on glacial outwash deposits tend to be poorly developed and coarse textured (gravelly sandy loam is typical). Terraces adjoining principal river channels are generally mantled with deep silt loam soils which remain moist throughout the year.

Southwestern Washington, which includes the Willapa and Black Hills, is a region of low, rounded hills largely comprised of Eocene sandstone and siltstone.

For the most part, soils tend to be deep, reddish-brown in color, and fairly fine-textured. Along the coast, small areas of sand dunes are present, especially in the Long Beach area.

Dense coniferous forest with associated fauna and the streams and rivers are the dominant biologic features of this province (Franklin and Dyrness 1973). Western hemlock, Sitka spruce, Douglas-fir, and western redcedar dominate at lower and true firs at higher elevations. The "Olympic rain forests" on the west slopes of the peninsula are well known, with their elk and epiphyte-draped trees. Subalpine parklands and alpine regions cover substantial areas in the Olympic Mountains. Substantial variation exists in these ecosystems, however, reflecting both

climatic differences and historical effects. The northeastern and eastern portions of the Olympic Peninsula are much drier than the remainder of this generally superhumid province. Douglas-fir and subalpine fir are more conspicuous in this drier region, and the alpine region is more extensive. The southwestern Washington Coast Ranges have been heavily altered by logging and are dominated by much younger, secondary forests of conifers and red alder.

The coastal areas add substantially to the biotic diversity of this province; distinctive ecosystems are associated, for example, with the sand dunes, rocky headlands and islands, coastal plain prairies and cedar swamps, and ocean-front forests.

Dominant freshwater systems are streams and rivers, some of glacial origin, oligotrophic lakes and ponds at higher elevations, and a variety of bog and swamp ecosystems on the coastal plain. Anadromous fish are an important biotic element in many of the river and stream systems.

Identified terrestrial cells in the Olympic Peninsula and southwestern Washington Coast Ranges total 27 (table 5). These consist largely of the major variants of the coniferous forests and the complex subalpine and alpine community mosaics. Five of the cells specifically identify necessary coverage of the specialized coastal front and plain communities.

Aquatic cells total 17 (table 6) and recognize a need for designation of major stream drainages on both sides of the peninsula as Research Natural Areas. Two cells recognize anadromous fish runs as necessary components (Nos. 1 and 11). The remaining cells are mainly small lakes and ponds in a variety of environments, and swamps, marshes, and bogs on the coastal plain.

It is presumed that the terrestrial and freshwater areas will include the normal complement of animal and plant species. Four animal species are listed as cells for Research Natural Area consideration because of their rare and endangered status (table 7). The list of vascular plants of special interest is relatively long (table 8) and includes 12 species on the Smithsonian list of endangered and threatened plants. This is a consequence of the presence of several endemic species as well as numerous disjunct populations in the isolated Olympic Mountain block; most of these are subalpine and alpine plants and are concentrated in the northeastern part of the peninsula. The other major group of vascular plants of special interest is associated mainly with specialized habitats (bogs, marshes, cliffs) on the coastal plain.

There are six existing Research Natural Areas in this province (table 9), mostly small and all Federal, with four located in Olympic National Park. These fill 8 of 27 terrestrial cells and none of the freshwater or rare and endangered animal cells.

Consequently there is a large number of Research Natural Areas which need to be selected and established in the Olympic Mountains and Coast Ranges of Washington (table 10). Our tentative estimate is that 22 additional Research Natural Areas can provide minimal coverage of all listed cells and a majority of special interest vascular plants. Six of these (Nos. 1-6) involve relatively large areas to encompass a variety of terrestrial and aquatic cells typically taking in a complete drainage system of a stream, lake, or pond. Most of the remainder involve smaller areas to encompass one or two cells. Because of the large number of special interest vascular plants at high elevations in the Olympic Mountains, an alpine tract focused on several of these will probably prove necessary in addition to inclusion of typical alpine ecosystems in need No. 5.

Lead responsibility in this province is clearly split between the National Park Service and Forest Service on the peninsula, with Washington State, assisted by private organizations and the Fish and Wildlife Service, critical in the Coast Ranges. Olympic National Park clearly will shoulder the greatest load in both the coastal plain and mountains of the peninsula; but even there, cellular needs cannot be fully met solely within the Park (see, for example, No. 2). One of the most difficult needs to fill may be the cedar swamp with ponds and anadromous fish (No. 3), but it is considered critical.

The priority ratings reflect the already protected status of ecosystems within Olympic National Park; the ecosystems in the heavily impacted and rapidly developing southwestern Coast Ranges clearly need immediate attention. Nevertheless it is important that selection and establishment of tracts in Olympic National Park proceed quickly, as they represent such a large element in the province's Research Natural Area needs.

Table 5.--*Terrestrial cells in the Olympic Peninsula and Southwestern Washington Province*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Western Hemlock Zone:			
1. Old-growth Douglas-fir on a major river terrace, west side of peninsula	229	Jackson Creek RNA	72-82
2. Douglas-fir-western hemlock on a marine terrace, west side of peninsula	230	Quinault RNA	72-82
3. Western hemlock/swordfern, west side of peninsula	224	Quinault and Higley Creek RNA's	77-78
4. Western redcedar-western hemlock on the coastal plain, west side of peninsula	227	Quinault RNA	79-82
* 5. Western redcedar-western hemlock on uplands	227	Token, needs additional area	79-82
* 6. Typical Douglas-fir-western hemlock forest on slopes, east side of peninsula	230	None	72-82
* 7. Douglas-fir-western hemlock/Oregongrape forest on slopes, east side of peninsula	230	None	82
* 8. Pure stand of red alder on upland site	221	None	61-63
Pacific Silver Fir Zone:			
* 9. Typical noble fir forest in Willapa Hills area	226	None	94-98
10. Pacific silver fir-western hemlock at low-elevation, west side of peninsula	226	Hades Creek RNA	94-98
*11. Pacific silver fir-western hemlock at mid- to high elevations, west side of peninsula	226	None	94-98
*12. Pacific silver fir/salal community on slopes, east side of peninsula	226	None	94-98
Sitka Spruce Zone:			
13. Sitka spruce-western hemlock/swordfern community	225	Twin Creek and Quinault RNA's	59-61
14. Second-growth Sitka spruce-western hemlock forest	225	Diamond Point RNA	59-61
*15. Sitka spruce/salal community ocean front	223	None	59-61

See footnote at end of table.

Table 5.--*Terrestrial cells in the Olympic Peninsula and Southwestern Washington Province* (Continued)

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
alpine and Alpine Zones:			
Mountain hemlock-Pacific silver fir forest in western Olympic Mountains	205	None	101-106
Subalpine fir forest in northeastern portion of Olympic Peninsula	206	None	101-106
Subalpine parkland mosaic with mountain hemlock and heather-huckleberry dominance, western Olympic Mountains	205	None	101-106 250-268
Subalpine parkland mosaic with subalpine fir and grass-forb dominance, eastern Olympic Mountains	206	None	101-106 250-268
Alpine community mosaic, including krummholz, northeastern Olympic Mountains		None	284-290
cial types:			
Western redcedar swamp on coastal plain with evergreen huckleberry understory and possibly patches of skunkcabbage	228	None	68-69
Typical red alder swamp	221	Higley Creek and Diamond Point RNA's	68-69
Typical riparian hardwoods (red alder-cottonwood)	221	None	66-67
Lodgepole pine forest, ocean front	216	None	291-294
Coastal sand dunes, including both active and stabilized dunes		None	291-294
Typical coastal prairie, west side of peninsula		None	69-70
Sitka spruce/willow community, tideland area	223	None	

*Cells presently lacking adequate representation.

Table 6.--*Aquatic cells in the Olympic Peninsula and Southwestern Washington Province*

Cell[1]	Present representation	Remarks
* 1. Major stream drainage with coniferous forest and anadromous fish run	None	Should be on west side of peninsula
* 2. Major stream drainage with coniferous forest on east side	None	Stream draining east slopes of Olympic Mountains
* 3. Oligotrophic lake at low elevation	None	
* 4. Lake and drainage basin of subalpine forest or forest and meadow	None	
* 5. Typical alpine lake and drainage basin	None	
* 6. Low-elevation permanent pond	None	
* 7. Subalpine permanent pond	None	
* 8. Alpine permanent pond	None	
* 9. Low-elevation vernal pond	None	
*10. Subalpine permanent pond	None	
*11. Stream draining western redcedar swamp, with anadromous fish	None	West side of peninsula
*12. Headwaters of a subalpine stream, one fork glacially fed, another fork nonglacial	None	
*13. Large, upwelling cold spring	None	
*14. Typical hot spring	None	
*15. Western redcedar swamp	None	
*16. Typical marsh area	None	
*17. Coastal bog	None	*Myrica* is typical shrub species

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 7.--*Rare and endangered vertebrate animal cells in the Olympic Peninsula and Southwestern Washington Province*

Cell	Verified representation	Reference
Fish:		
*1. Olympic mudminnow	None	
Amphibians:		
*2. Dunn salamander	None	Stebbins 1954
Mammals:		
*3. Western pocket gopher (subspecies *melanops*)	None	Dalquest 1948 Johnson and Johnson 1952
*4. Heather vole	None	Dalquest 1948 Johnson and Johnson 1952 Maser and Storm 1970 Edwards 1955 Johnson 1973 Shaw 1924

*Cells presently lacking adequate representation.

Table 8.--*Vascular plants of special interest in the Olympic Peninsula and Southwestern Washington Province*

Species[1]	Distribution
Anemone oregana var. *felix*[2]	Marshes or sphagnum bogs, Grays Harbor County
Arenaria paludicola[2]	Coastal southwestern Washington
Argostis aequivalvis	Bogs, Lake Ozette north
Aster paucicapitatus	Subalpine parkland, Olympic Mountains
Astragalus cottonii	Alpine talus, Olympic Mountains
Botrychium lanceolatum	High-elevation, moist areas
Botrychium virginianum	Broad elevational range
Calamagrostis crassiglumis	Around lakes; subalpine rock crevices, Olympic Mountains
Campanula piperi	Peat bogs and swampy woods, Grays Harbor County north
Carex pluriflora	Marshes and streambanks, south to Clallam County
Castilleja parviflora var. *olympica*[2]	Subalpine meadows, Olympic Mountains
Cheilanthes lanosa	Olympic Mountains
Cimicifuga elata	Lower elevations
Delphinium nuttallii	Outwash prairies and basaltic cliffs, Grays Harbor County south
Douglasia laevigata	Northeastern Olympic Mountains
Draba incerta	Olympic Mountains
Eburophyton austiniae	Deep coniferous forest
Elmera racemosa	Olympic Mountains
Erigeron aliceae	Olympic Mountains
Erigeron flettii[2]	Higher elevations, Olympic Mountains
Erysimum arenicola var. *arenicola*	Higher elevations, Olympic Mountains
Erythronium revolutum	Widely distributed
Gentiana douglasiana	Lake Ozette area
Geum triflorum var. *campanulatum*	Olympic Mountains
Hedysarum occidentale	Olympic Mountains
Howellia aquatilis	Ponds and lakes
Lewisia columbiana var. *rupicola*	Olympic Mountains
Lomatium martindalei var. *flavum*[2]	Olympic Mountains
Myrica californica	Coastal dune habitats, Grays Harbor County south
Myrica gale	Coastal bogs, Grays Harbor County south
Nephrophyllidium crista-galli	Bogs and wet meadows, Olympic Peninsula

See footnotes at end of table.

Table 8.--*Vascular plants of special interest in the Olympic Peninsula and Southwestern Washington Province* (Continued)

Species[1]	Distribution
Oxytropis viscida	Olympic Mountains
Pedicularis bracteosa var. *atrosanguinea*	Olympic Mountains
Petrophytum hendersonii[2]	Olympic Mountains
Phacelia bolanderi	Wahkiakum County
Pleuricospora fimbriolata	Olympic Mountains
Poa pachypholis[2]	Rare endemic on ocean cliffs, Pacific County
Polemonium carneum	
Polypodium scouleri	Epiphyte in dunes and salt spray zone
Polystichum andersonii	
Polystichum kruckebergii[2]	Hurricane Ridge, Olympic Mountains
Ranunculus cooleyae	Mount Colonel Bob, Olympic Mountains
Ribes lobbii	Disjunct reported on Olympic Peninsula
Romanzoffia tracyi	Along coast of Olympic Peninsula
Sanguisorba menziesii	Southern limit in Olympic Mountains
Saxifraga oppositifolia	Olympic Mountains
Senecio flettii	Moderate to high elevations, Olympic Mountains
Senecio websteri[2]	Endemic at high altitudes, Olympic Mountains
Sisyrinchium californicum	Bogs near coast
Stellaria humifusa	Widely disjunct in salt marshes
Synthyris pinnatifida var. *lanuginosa*[2]	Alpine endemic, Olympic Mountains
Synthyris schizantha[2]	Moist shaded cliffs at moderate to high elevations, Olympic Peninsula
Viola flettii[2]	Subalpine to alpine, northeastern Olympic Mountains

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]The species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 9.--*Established Research Natural Areas in the Olympic Peninsula and Southwestern Washington Province*

Name	Principal features	Agency[1]	Area	
			Ha	Acres
Diamond Point RNA	Sitka spruce-western hemlock forest on an island in Willapa Bay	FWS	36	88
Hades Creek RNA	Low-elevation Pacific silver fir-western hemlock forest	NPS	227	560
Higley Creek RNA	Western hemlock forests	NPS	194	480
Jackson Creek RNA	Douglas-fir forest	NPS	65	160
Quinault RNA	Western hemlock-Sitka spruce forests	FS	594	1,468
Twin Creek RNA	Sitka spruce stands of "rain forest" type	NPS	40	100

[1] FS = Forest Service, FWS = Fish and Wildlife Service, NPS = National Park Service.

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic natural areas:						
1. Large stream drainage on western slopes of Olympics with Sitka spruce-western hemlock and Pacific silver fir-western hemlock forest	T-11,13,10 A-1 R&E-1,2	Expansion of Twin Creek RNA may fill this need	Medium	NPS	64-67 94-98	0103
2. Large stream drainage on eastern slopes of Olympics with Douglas-fir-western hemlock/Oregongrape forest	T-7,12 A-2	May have to be joint FS-NPS RNA	High	FS NPS	82	0102
3. Western redcedar swamp with ponds and stream with anadromous fish	T-21,4,5 A-6,11,15	Ocean strip of Olympic National Park	High	NPS FS	68-69	0104
4. Mountain hemlock-Pacific silver fir forest, subalpine parkland mosaic, lakes, and ponds	T-16,18 A-4,7,10 R&E-3,4	Western portion of Olympic Mountains, Olympic National Park	Medium	NPS	101-106 250-268	0105
5. Subalpine fir forest, subalpine parkland mosaic, alpine community mosaic, lakes, and ponds	T-17,19,20 A-4,5,7,8,10 R&E-4	Northeastern portion of Olympic Mountains, Olympic National Park (Hurricane Ridge Area)	Medium	NPS	101-106 250-268 284-290	0105
6. Riparian hardwood forest (red alder-cottonwood) along a major river and vernal ponds	T-23 A-9	Along Hoh River or tributaries to Quinault River	Low	NPS	66-67	0103 0104
Predominantly terrestrial natural areas:						
7. Ocean-front Sitka spruce/salal community	T-15	West coast of Olympic Peninsula	Medium	NPS	59-61 291-294	0104
8. Ocean-front lodgepole pine forest	T-24	Leadbetter Point	Medium	State	291-294	0202
9. Western redcedar-western hemlock forest	T-5	Long Island	High	State	79-82	0202
10. Upland red alder forest	T-8	Northwestern portion of Olympic Peninsula	Low	State Private	61-63	0103
11. Coastal sand dunes	T-25	Needs prograding dunes on north or south side of feeding river, both active and stabilized. Leadbetter Point or Fort Stevens	High	State FWS	291-294	0202
12. Pacific silver fir/salal community on east side of Peninsula	T-12		High	FS NPS	94-98	0102
13. Typical coastal prairie	T-26 R&E-3	Proposed Pats Prairie RNA may fill need	Medium	FS NPS	69-70	0104

See footnotes at end of table.

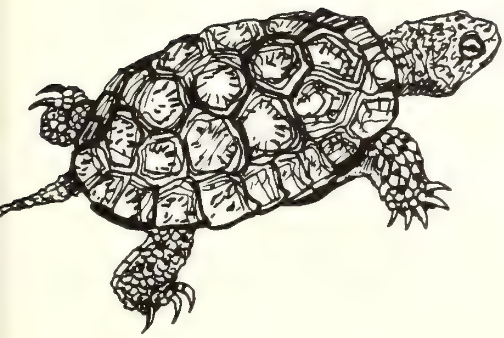
Table 10.--*Additional Research Natural Areas needed in the Olympic Peninsula and Southwestern Washington Province* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
14. Douglas-fir-western hemlock and noble fir forest in the Willapa Hills area	T-<u>6</u>,<u>9</u>	Weyerhaeuser Company ownership	High	Private State	79-80 94-98	0202
15. Sitka spruce/willow in tideland habitat	T-<u>27</u>	North Hunting Island	High	FWS		
<u>Predominantly aquatic natural areas:</u>						
16. Low elevation oligotrophic lake	A-<u>3</u>	Fern Lake is candidate area	Medium	State		0104
17. Subalpine stream with two major tributaries--one glacially fed, the other nonglacial	A-<u>12</u>	Olympic National Park	Medium	NPS		0101
18. Large, upwelling cold spring	A-<u>13</u>		Low	NPS State		
19. Typical hot springs area	A-<u>14</u>		Medium	NPS State		
20. Low elevation marshland	A-<u>16</u>		Medium	NPS Private State	68-69	0104
21. Typical coastal bog (*Myrica*)	A-<u>17</u>		Medium	NPS Private State		0104
<u>Natural area for special interest species:</u>						
22. Alpine tract		Northeastern Olympic Peninsula; area with populations of several vascular plants of special interest such as *Senecio websteri*, *Synthyris pinnatifida*, and *Viola flettii*	Medium	NPS FS		

[1]For a description of these cells see table 5 for terrestrial (T) ecosystems, table 6 for aquatic (A) ecosystems, and table 7 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate cells considered essential components of the proposed Research Natural Area; those not underlined represent cells which would be desirable but not essential.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of that type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. FS = Forest Service, FWS = Fish and Wildlife Service, NPS = National Park Service.



GET TROUGH PROVINCE, WASHINGTON

The Puget Trough Province has two main sections—the northern half, which includes Puget Sound, and the southern half, largely made up of the Cowlitz River valley and upper basin of the Chehalis River (fig. 1). In both sections relief is moderate, with the elevation of the trough floor seldom exceeding 160 m.

The northern portion of the province is a depressed, glaciated area which is now partially submerged (Puget Sound). Both geology and topography have been strongly influenced by a series of glaciers which pushed into the area from the north during the Pleistocene. The receding ice masses left a large, gently sloping area stretching approximately 20 km south of Olympia. This area contains many lakes and poorly drained depressions underlain by glacial drift. Soils formed on glacial till under coniferous forest vegetation are generally coarse-textured Brown Podzolics, with a thin A2 horizon underlain by an iron- and humus-enriched B horizon.

The major portion of the southern half of the province is underlain by Eocene basalt flows and flow breccia. Pleistocene lacustrine deposits are also common in the area immediately north of the Columbia River. Soils derived from basalt commonly have well-aggregated silt loam to clay loam surface horizons underlain by B horizons generally showing evidence of clay accumulation. Other soils in this southern section include dark-colored, fine-textured soils formed under grass, and soils containing large amounts of volcanic pumice.

The ecosystems of this province have, for the most part, been strongly influenced by human activity. Secondary coniferous forests, developed following earlier logging, dominate. They are typically composed of Douglas-fir and western hemlock, with lodgepole and western white pine conspicuous associates of Douglas-fir on some sites in the glaciated northern half. Even aside from disturbance, many ecosystems are very distinctive from those in the mountains to the east and west. Many sites, especially in the northern section, have been glacially influenced with outwash soils, bogs, and lakes. In addition, this province has a markedly drier climate since it lies in the rain shadow of the coastal mountain systems. Consequently, substantial and important diversity is represented in the communities and constituent species.

The list of identified terrestrial cells totals 16 (table 11). Seven of these are forest types, including typical coniferous forests on residual soils and glacial till. Four represent a mosaic of forest, savanna, and prairie which is found mainly at the southern end of Puget Sound and in the San Juan Islands. Three of the special ecosystem cells (Nos. 12, 14, and 15) are also found in these two areas which are obvious concentrations of biotic diversity. The remaining terrestrial cells (Nos. 13 and 16) involve flood plain communities along the Columbia River.

There are eight aquatic cells identified at present (table 12). It is expected that the majority of these would be found in glaciated areas in the northern half of the province.

Terrestrial and aquatic areas presumably will include the normal complement of species. The list of rare and endangered vertebrate animals requiring specific consideration totals four (table 13). The list of vascular plants of special interest is relatively short but includes four from the Smithsonian list of threatened and endangered species (table 14). This list again identifies the prairie region at the south end of Puget Sound and the San Juan Islands as areas of particular significance (see terrestrial cells Nos. 8-12, 14, and 15). Several of the plants are also associated with the dry Douglas-fir - Pacific madrone / rhododendron forests along the Hood Canal and eastern margin of the Olympic Mountains (terrestrial cell No. 3).

At present there are only two identified Research Natural Areas within the Puget Trough Province (table 15). These two areas fill 3 of the 28 cells listed (2 terrestrial and 1 aquatic).

Our estimate is that 17 additional Research Natural Areas will provide for a minimal system in the Puget Trough Province (table 16). Most Research Natural Areas can be relatively small (under 500 acres, or 202 ha) since they are generally focused on one or two cells. Aquatic areas involving an entire drainage for lakes or small streams (items 12-14 in table 16) would probably be the largest.

Identifying and establishing the necessary Research Natural Areas in this province may be difficult because of existing and potential human developments. Obviously, the major responsibility is upon State and private institutions. Department of Defense, particularly because of its Fort Lewis holdings, is in a unique position to provide representation of some of the major community mosaics (prairie, savanna, ponderosa pine) found on the glacial outwash at the south end of the sound. The Fish and Wildlife Service also has an important role in some specific needs.

The fast pace of development in this province necessitates that Research Natural Area establishment be given high priority. Consequently, most needs (table 16) are given high or medium priority because of the danger suitable areas will be lost.

Table 11.--*Terrestrial cells in Puget Trough Province, Washington*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
est types (Western Hemlock Zone):			
. Douglas-fir-western white pine/salal on glacial till	229	None	88-89
. Douglas-fir (>100 years old)/salal on glacial till	229	None	88-89
. Douglas-fir-madrone/rhododendron on glacial till, just west of Hood Canal	229	None; consider vascular plants of special interest	88-89
. Mature Douglas-fir-western hemlock with mixed understory (Oregongrape, salal, and swordfern types)	230	None	88-89
. Western redcedar-western hemlock/swordfern on residual soil, Capitol Hills or eastern Willapa Hills	227	None	79-82
. Lodgepole pine/salal on glacial till	216	None	88-89
. Red alder/swordfern on glacial till	221	None	82-89
irie and savanna types:			
. Ponderosa pine on glacial till in the Fort Lewis area	245	None	88-89
. Prairie, oak woodland, conifer forest mosaic in Olympia-Tacoma area	229 233	Token, need additional area	88-89
. Oregon white oak woodland	233	Token, need additional area	88-89
. San Juan Islands forest-steppe mosaic with hardwood and coniferous woodland and fescue grassland		None	313
cial types:			
. Mima mounds		Minimal representation	89-90
. Riparian black cottonwood/willow along lower Columbia River		Token in Blackwater Island RNA, need additional area	295-296
. *Juniperus scopulorum* in San Juan Islands		None	313
. Serpentine vegetation plus basalt contact on Puget Sound island		None	309
. Channeled basalt in flood plain of Columbia River with Douglas-fir and Oregon white oak stands, shrub communities, and grasslands		Blackwater Island	

*Cells presently lacking adequate representation.

Table 12.--*Aquatic cells in the Puget Trough Province, Washington*

Cell[1]	Present representation	Remarks
*1. Oligotrophic lake in glaciated topography and drainage basin of temperate forest	None	
*2. Eutrophic oxbow lake and drainage basin	None	
*3. Permanent pond	None	
*4. Typical stream drainage	None	
*5. Large, upwelling cold spring	None	
*6. Marshland area	None	
*7. Typical bog	None	*Ledum* is common shrub
8. Vernal ponds and marshes in channeled basalt, Columbia River flood plain	Blackwater Island RNA	

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 13.--*Rare and endangered vertebrate animal cells in the Puget Trough Province, Washington*

Cell	Verified representation	Reference
Reptiles:		
*1. Western pond turtle	None	Stebbins 1954
*2. Sharp-tailed snake	None	Stebbins 1954
*3. Pacific ringnecked snake	None	Stebbins 1954
Mammals:		
*4. Masked shrew (subspecies *hollisteri*)	None	Dalquest 1948

*Cells presently lacking adequate representation.

Table 14.--*Vascular plants of special interest in the Puget Trough Province, Washington*

Species[1]	Distribution
Arctostaphylos media	Hybrid, Mason and Kitsap Counties
Arenaria paludicola[2]	Tacoma prairies south
Aster curtus[2]	On prairies at south end of Puget Sound
Boschniakia hookeri	Kitsap and Mason Counties
Botrychium virginianum	Moist areas
Castanopsis chrysophylla	Eastern edge of Olympic Peninsula
Delphinium nuttallii	Outwash prairies
Erythronium oregonum[2]	
Erythronium revolutum	
Habenaria chorisiana	One bog in Snohomish County
Hemitomes congestum	Coastal forests
Howellia aquatilis	
Iris missuriensis	Disjunct on Whidbey Island
Iris tenax	Centralia south
Isopyrum hallii	Moist woods, Lewis and Thurston Counties south
Juniperus scopulorum	San Juan Islands
Lepidium virginicum var. *menziesii*	Littoral endemic
Meconella oregana	
Opuntia fragilis	Disjuncts at Sequim and San Juan Islands
Pinus ponderosa	Outwash in Tacoma-Olympia area
Rhododendron macrophyllum	Along Hood Canal
Salix fluviatilis[2]	Along Columbia River
Woodwardia fimbriata	Few widely disjunct populations

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]The species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 15.--*Established Research Natural Areas in the Puget Trough Province, Washington*

Name	Principal features	Agency[1]	Area Ha	Area Acres
Blackwater Island RNA	Oregon white oak-Douglas-fir grassland, and willow, Oregon ash in lower portions of channeled basalt along Columbia River	FWS	52	129
Mima Mounds RNA	Mima mound phenomenon and associated vegetation near Olympia, Washington	ESC	222	548

[1]ESC = Evergreen State College, FWS = Fish and Wildlife Service.

Table 16.--*Additional Research Natural Areas needed in the Puget Trough Province, Washington*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Predominantly terrestrial natural areas:						
1. Douglas-fir-western white pine on glacial till	T-1 R&E-4		Medium	Private	88-89	0404
2. Douglas-fir/salal and lodgepole pine/salal communities on glacial till	T-2,6	Douglas-fir should be over 100 years old	Medium	Private	88-89	0404
3. Douglas-fir-madrone/rhododendron community on glacial till	T-3 R&E-2,3	Located just west of Hood Canal	High	State Private	88-89	0404
4. Mature Douglas-fir-western hemlock with mixed understory on fine-textured glacial till	T-4 R&E-4	Area in Pack Forest is potential site	Medium	State	88-89	0402
5. Western redcedar-western hemlock/swordfern community on residuum	T-5	Capitol Hills or eastern Willapa Hills	High	State Private	79-82	0202
6. Ponderosa pine on glacial till	T-8 R&E-2,3	Fort Lewis area	Low	Department of Defense	88-89	0403
7. Puget prairie-woodland mosaic with Oregon white oak	T-9,10 R&E-2,3		High	Private State	88-89	0402 0403
8. Red alder/swordfern community on glacial till	T-7	Alderwood soil	Low	Private	82-89	0403 0404
9. Riparian black cottonwood-willow (along lower Columbia River)	T-13	Several FWS areas in process of establishment	Medium	FWS	295-296	
10. San Juan Islands forest-steppe mosaic with *Juniperus scopulorum*	T-11,14		High	Private	313	0402
11. Serpentine vegetation plus basalt contact on an island in Puget Sound	T-15	Cypress Island is possible location	High	Private	309	0402

See footnotes at end of table.

Table 16.--*Additional Research Natural Areas needed in the Puget Trough Province, Washington* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Predominantly aquatic natural areas:						
12. Oligotrophic lake in glaciated topography and drainage basin of temperate forest	A-1,3		High	Private		0403 0404
13. Eutrophic oxbow lake and drainage basin	A-2 R&E-1		High	Private		0403 0404
14. Typical stream drainage	A-4	Fort Lewis area	High	Private Department of Defense		0402 0403
15. Large, upwelling cold spring	A-5		Low	Private		
16. Marshland area	A-6		High	Private		0403
17. *Ledum* bog	A-7	Snohomish County	Medium	Private		0403

[1]For a description of these cells see table 11 for terrestrial (T) ecosystems, table 12 for aquatic (A) ecosystems, and table 13 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate those cells which are considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential components.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of the type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. FWS = Fish and Wildlife Service.

[4]See appendix V.

ESTERN SLOPES AND CREST PROVINCE, ASHINGTON CASCADES

This province (fig. 1) is a rugged mountain region composed of two major geologic units. South of Snoqualmie Pass, bedrock is primarily Eocene to Miocene andesites and basalts. The northern portion of the province is made up of considerably older (largely Paleozoic and Cretaceous) sedimentary and metamorphic rocks, interspersed with large granitic intrusions.

Topographically, the southern section is characterized by generally accordant ridge crests separated by steep, deeply dissected valleys. Three Pleistocene volcanic cones tower above their surroundings—Mount Adams, Mount Rainier, and Mount St. Helens. An extensive area around Mount Adams is covered by recent lava flows and comprises a gently sloping plateau.

North of Snoqualmie Pass, the Cascade Range is extremely rugged. Valleys are deep and steep-sided, containing low-gradient streams. Glacially formed cirques and matterhorns are abundant, attesting to the profound effect glaciation has had in shaping landforms. Glaciers are still common; this region contains more active glaciers than any other area within the continental United States.

Soils in the southern portion of the Washington Cascades are most often Podzolic sandy loams or loamy sands formed in layers of pumice or volcanic ash overlying basalt or andesite. To the north, finer textured glacial and glaciolacustrine soils are especially common in many of the broad valley bottoms. On steep side slopes, shallow residual soils are commonly gravelly sandy loam in texture.

The natural communities of this province reflect the generally wet, moderate to cool climatic regime. Coniferous forests, arranged in three major elevational zones (western hemlock, Pacific silver fir, and mountain hemlock), dominate the slopes and valley bottoms. There is a substantial diversity in these coniferous forest communities reflecting differing environments and successional stages, largely as a consequence of periodic fires. Subalpine meadow-forest parklands cover the bulk of relatively narrow regions between closed forest and the regions of permanent snow and ice on the higher peaks. These parklands are typically intricate mosaics of many different community types.

Freshwater systems found in this province are largely streams and rivers including "milky" glacier-fed types and ponds and relatively small lakes over a broad range of elevations.

Specialized habitats add substantial diversity to the province. First there is the normal array of nonforested communities within a forest mosaic—bogs, marshes, shrub communities on scree and avalanche tracks, etc. A major serpentine outcrop (around Twin Sisters near Mount Baker), the unusually arid (for this province) Ross Lake region on the Skagit River, and the area around Columbia River Gorge provide major centers for distinctive biotic arrays. Lava flows, hot springs, and pumice fields are additional features associated with the major volcanic peaks.

Identified terrestrial cells total 31 (table 17). The dominant coniferous forests and their associated biota are emphasized in the cellular listing, which recognizes the need to represent variations of some widespread types by providing Research Natural Areas in both the northern and southern half of the province. The list also reflects the need to provide examples of widespread community types representing relatively early successional stages (see cell Nos. 1, 2, and 15 in table 17). The list of terrestrial cells is rounded out with subalpine meadow and parkland communities and other types representing unusual or youthful substrates (lava flows, serpentine) or extreme environments.

The list of aquatic cells (table 18) provides for examples of the typical ecosystems found in the several life zones and totals 18.

It is presumed that the terrestrial and freshwater areas will incorporate the typical complement of animal and plant species. There are eight vertebrate animal species which are listed for consideration as rare and endangered cells in Research Natural Area selection (table 19). The plant list includes 13 species from the Smithsonian list of threatened and endangered plants (table 20). There are several obvious areas of concentration—the Columbia River Gorge, high elevations around Mount Rainier and Mount Adams, and serpentine areas.

Substantial progress has been made in establishment of Research Natural Areas in this province. The 11 existing Research Natural Areas (table 21), all in Federal ownership, provide coverage of nearly half of the identified cells (24 out of 57 terrestrial, aquatic, and rare and endangered cells). Existing National Parks and Wilderness Areas also provide substantial protection for many of the rare and endangered species, provided they are considered in the management plans for these tracts.

Nevertheless, a substantial job in locating and establishing Research Natural Areas remains. We estimate 21 additional Research Natural Areas are needed to provide minimal coverage of all of the listed cells (table 22).

Lead responsibility in this province lies with the Forest Service and National Park Service who control most of the land. The three large combined terrestrial and aquatic areas are most likely to be found in the North Cascades National Park complex. The low-elevation lake (need No. 13) will probably be one of the most difficult to locate. A subalpine lake in City of Seattle ownership within the Cedar River watershed (Findley Lake) may fill need No. 14. State ownership should also be considered in the search for need No. 4, young Douglas-fir in an old burn.

Table 17.--*Terrestrial cells in the Western Slopes and Crest Province, Washington Cascades*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Western Hemlock Zone:			
* 1. Douglas-fir <75 years old (old burn)	229	Token, need additional area	82-88
* 2. Douglas-fir 100-150 years old	229	Token, need additional area	82-88
3. Old-growth Douglas-fir-western hemlock forest, northern portion of province	230	North Fork Nooksack RNA	72-82
4. Old-growth Douglas-fir-western hemlock forest, southern portion of province	230	Wind River and Cedar Flats RNA's	72-82
5. Old-growth western hemlock forest, northern portion of province	224	Long Creek RNA	72-82
6. Old-growth western hemlock forest, southern portion of province	224	Wind River RNA	72-82
* 7. Old-growth western redcedar forest, northern portion of province	228	None	81-82
8. Old-growth western redcedar forest, southern portion of province	228	Cedar Flats RNA	81-82
9. Old-growth western redcedar-western hemlock forest	227	North Fork Nooksack, Long Creek, and Lake Twentytwo RNA's	81-82
*10. Red alder forest	221	Token stand of climax red alder at Long Creek RNA; need additional area	82-88
Pacific Silver Fir Zone:			
11. Pacific silver fir-western hemlock forest, northern portion of province	226	North Fork Nooksack and Lake Twentytwo RNA's	94-98
12. Pacific silver fir-western hemlock forest, southern portion of province	226	Butter Creek and Sister Rocks RNA's	94-98
*13. Pacific silver fir forest, northern portion of province	226	None	94-98
14. Pacific silver fir forest, southern portion of province	226	Sister Rocks and Steamboat Mountain RNA's	94-98
15. Noble fir forest (typical)	226	Butter Creek and Goat Marsh RNA's	94-98

See footnote at end of table.

Table 17.--*Terrestrial cells in the Western Slopes and Crest Province, Washington Cascades* (Continued)

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Mountain Hemlock Zone:			
*16. Mountain hemlock-Pacific silver fir forest, northern portion	205	None	103-106
17. Mountain hemlock-Pacific silver fir forest, southern portion	205	Steamboat Mountain and Butter Creek RNA's	103-106
18. Typical subalpine fir forest	206	Steamboat Mountain RNA	103-106
*19. Alaska-cedar (in stand with mountain hemlock and subalpine fir)	228	None	103-106
Subalpine and alpine meadows and parkland:			
*20. Subalpine parkland mosaic (tree groups with a variety of meadow types)		Token, need another area	250-268 277-281
*21. Heather-huckleberry communities		Token, need another area	251-256
*22. Subalpine lush herbaceous communities, including *Valeriana-Veratrum* and *Rubus parvifolium-Pteridium* types		Token, need another area	256-261
23. Subalpine green fescue community		Butter Creek RNA	263-264
*24. Alpine community mosaic with krummholz tree groups		None	
Special types:			
*25. Lodgepole pine-Douglas-fir at Ross Lake	216 229	None	312
*26. Ponderosa pine forest at Ross Lake	245	None	312
*27. Recent lava flow with open forest and shrub cover		None	300-302
28. Recent mud flow with lodgepole pine cover		Goat Marsh RNA	302-304
29. Recently exposed glacial moraine and outwash		Boston Glacier RNA	284-290
30. Sitka alder and vine maple avalanche tracks		North Fork Nooksack, Lake Twentytwo, and Butter Creek RNA's	91 100-101
*31. Representative serpentine area in the North Cascades		None	309

*Cells presently lacking adequate representation.

Table 18.--*Aquatic cells in the Western Slopes and Crest Province, Washington Cascades*

Cell[1]	Present representation	Remarks
* 1. Major stream drainage covered with temperate coniferous forest	None	
2. Major stream drainage covered with subalpine forest mosaic	Butter Creek RNA	
* 3. River valley bottom mosaic of terrestrial, semiaquatic, and aquatic communities	None	Should be in North Cascades
* 4. Low elevation lake and drainage basin of temperate forest	None	
* 5. Lake and drainage basin of subalpine forest or forest and meadow, without fish	None	
6. Marsh and swamp ecosystem	Goat Marsh, Cedar Flats, Wind River, Steamboat Mountain RNA's	
7. Cirque lake in alpine area	Pyramid Lake RNA	
* 8. Lake and drainage basin of subalpine forest or forest and meadow, with fish	None	
9. Subalpine permanent ponds	Butter Creek RNA	
*10. Alpine permanent ponds	None	Should be in North Cascades
11. Subalpine vernal ponds	Butter Creek RNA	
*12. Alpine vernal ponds	None	
*13. Subalpine stream which is glacially fed ("milkwater" stream)	None	
*14. Large, upwelling cold spring	None	
*15. Typical hot springs	None	
*16. Western redcedar swamp	Token representation on Cedar Flats RNA	Need additional area
17. Marsh area	Goat Marsh RNA	
18. Bog area	Steamboat Mountain and Goat Marsh RNA's	

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 19.--*Rare and endangered vertebrate animal cells in the Western Slopes and Crest Province, Washington Cascades*

Cell	Verified representation	Reference
Amphibians:		
*1. Larch Mountain salamander	None	Stebbins 1954
Reptiles:		
*2. Pacific ringnecked snake	None	Stebbins 1954
*3. California mountain kingsnake	None	Stebbins 1954
*4. Oregon alligator lizard	None	Stebbins 1954
Birds:		
*5. Cascade boreal chickadee	None	Alcorn 1971
Mammals:		
*6. Masked shrew (subspecies *hollisteri*)	None	Dalquest 1948
*7. Heather vole	Token at Steamboat Mountain RNA; need additional area	Dalquest 1948 Johnson and Johnson 1952 Maser and Storm 1970 Edwards 1955 Johnson 1973 Shaw 1924
*8. Northern bog lemming	None	Dalquest 1948 Maser and Storm 1970

*Cells presently lacking adequate representation.

Table 20.--*Vascular plants of special interest in the Western Slopes and Crest Province, Washington Cascades* (Continued)

Species[1]	Distribution
Lewisia columbiana var. *rupicola*	Mount Rainier
Loiseleuria procumbens	Trapper Peak in Skagit River drainage
Luina stricta	Mount Rainier south
Luzula arcuata	Mount Rainier
Lycopodium obscurum	Skagit County
Menyanthes trifoliata	Montane lakes; protected at Goat Marsh RNA
Pedicularis bracteosa var. *bracteosa*	Disjunct from Canada on Mount Adams
Pedicularis rainierensis[2]	High-elevation Mount Rainier endemic
Pellaea glabella var. *simplex*	Columbia River Gorge
Pleuricospora fimbriolata	
Polemonium carneum	
Polemonium elegans	Alpine
Polypodium montense	Mainly Columbia River Gorge
Polystichum andersonii	
Polystichum kruckebergii[2]	Bird Creek Meadows on Mount Adams
Polystichum lonchitis	Wet, moss-covered talus
Polystichum mohrioides	On serpentine
Ranunculus cooleyae	Del Campo Peak, Snohomish County
Rhododendron macrophyllum	Widely disjunct, Copper Creek near Mount Rainier, Wind River RNA
Salix fluviatilis[2]	Along Columbia River
Saxifraga cernua	
Saxifraga debilis	
Saxifraga lyallii	Whatcom County
Saxifraga oppositifolia	
Selaginella douglasii	Columbia River Gorge
Senecio elmeri	Alpine
Senecio flettii	Mid- to high-elevations, Mount Rainier area
Silene douglasii var. *monantha*	Columbia Gorge area
Silene suksdorfii	Mounts Rainier and Adams
Synthyris schizantha[2]	Moist shaded cliffs near Mount Rainier
Tauschia stricklandii[2]	Endemic to Mount Rainier subalpine

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]The species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 20.--*Vascular plants of special interest in the Western Slopes and Crest Province, Washington Cascades* (Continued)

Species[1]	Distribution
Lewisia columbiana var. *rupicola*	Mount Rainier
Loiseleuria procumbens	Trapper Peak in Skagit River drainage
Luina stricta	Mount Rainier south
Luzula arcuata	Mount Rainier
Lycopodium obscurum	Skagit County
Menyanthes trifoliata	Montane lakes; protected at Goat Marsh RNA
Pedicularis bracteosa var. *bracteosa*	Disjunct from Canada on Mount Adams
Pedicularis rainierensis[2]	High-elevation Mount Rainier endemic
Pellaea glabella var. *simplex*	Columbia River Gorge
Pleuricospora fimbriolata	
Polemonium carneum	
Polemonium elegans	Alpine
Polypodium montense	Mainly Columbia River Gorge
Polystichum andersonii	
Polystichum kruckebergii[2]	Bird Creek Meadows on Mount Adams
Polystichum lonchitis	Wet, moss-covered talus
Polystichum mohrioides	On serpentine
Ranunculus cooleyae	Del Campo Peak, Snohomish County
Rhododendron macrophyllum	Widely disjunct, Copper Creek near Mount Rainier, Wind River RNA
Salix fluviatilis[2]	Along Columbia River
Saxifraga cernua	
Saxifraga debilis	
Saxifraga lyallii	Whatcom County
Saxifraga oppositifolia	
Selaginella douglasii	Columbia River Gorge
Senecio elmeri	Alpine
Senecio flettii	Mid- to high-elevations, Mount Rainier area
Silene douglasii var. *monantha*	Columbia Gorge area
Silene suksdorfii	Mounts Rainier and Adams
Synthyris schizantha[2]	Moist shaded cliffs near Mount Rainier
Tauschia stricklandii[2]	Endemic to Mount Rainier subalpine

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]The species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 21.--*Established Research Natural Areas in the Western Slopes and Crest Province, Washington Cascades*

Name	Principal features	Agency[1]	Area	
			Ha	Acres
Boston Glacier RNA	Major alpine glacier and cirque basin in northern Cascade Range including some recently deglaciated topography	NPS	1 061	2,620
Butter Creek RNA	Subalpine mosaic of forest meadow and shrub communities with ponds and including a major stream drainage	NPS	810	2,000
Cedar Flats RNA	Western redcedar and associated swamps and marshes and Douglas-fir forest	FS	275	680
Goat Marsh RNA	Extensive mountain marshes, record noble fir forest, beaver swamp, ponds, and lodgepole pine on recent mudflow	FS	484	1,195
Lake Twentytwo RNA	Western redcedar-western hemlock forests and subalpine lake	FS	320	790
Long Creek RNA	Western hemlock forests	FS	259	640
North Fork Nooksack RNA	Douglas-fir and western hemlock forests	FS	605	1,495
Pyramid Lake RNA	Subalpine lake with surrounding conifer forest	NPS	48	119
Sister Rocks RNA	Pacific silver fir forests	FS	87	215
Steamboat Mountain RNA	Subalpine fir, Pacific silver fir, and mountain hemlock forest along with pond and marshes	FS	567	1,400
Wind River RNA	Douglas-fir-western hemlock forests	FS	478	1,180

[1]FS = Forest Service, NPS = National Park Service.

Table 22.--*Additional Research Natural Areas needed in the Western Slopes and Crest Province, Washington Cascades*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic natural areas:						
1. Mature coniferous forest mosaic and major stream drainage supporting full range of aquatic life	T-3,5,7,9, 11 A-1 R&E-8	Goodell Creek or Stetattle Creek in North Cascades National Park	High	NPS	72-82	0701 0702 0703
2. River valley bottom mosaic of mature conifer forest, semiaquatic, and aquatic communities	T-7,3,5,11 A-3,6,16,9 18	Big Beaver Creek or Chilliwack River, North Cascades National Park	High	NPS	72-82	0701
3. Alpine community mosaic with krummholz and ponds	T-24 A-10,12 R&E-6,7	With attention to special plants, e.g., *Botrychium* ssp., *Collomia larseni*, *Draba aureola*, and *Hulsea nana*; Mount Rainier or North Cascades National Park	Medium	NPS	276-290	0901 0704
Predominantly terrestrial natural areas:						
4. Douglas-fir less than 75 years old in an old burn	T-1	Yacolt Burn	Low	FS	82-88	0606
5. Douglas-fir in the 100- to 150-year-old age class	T-2	Wind River Experimental Forest	Low	FS	82-88	0904
6. Pacific silver fir and Pacific silver fir-mountain hemlock in the North Cascades	T-13,16	North Cascades National Park	Low	NPS	94-98 103-106	0703
7. Subalpine parkland mosaic with Alaska-cedar	T-19,20 A-11 R&E-5,6,7	North Cascades National Park	Medium	NPS	250-268 277-281	0704
8. Subalpine heather-huckleberry and lush herbaceous communities	T-21,22 R&E-7	Proposed Green Mountain RNA would at least partially fill this need	Medium	NPS	251-261	0704
9. Lodgepole pine-Douglas-fir and ponderosa pine forest in Ross Lake area	T-25,26	Ross Lake National Recreation Area	Low	NPS	312	0702
10. Recent lava flow and adjacent non-lava area	T-27	Big Lava Beds area (Gifford Pinchot National Forest)	Medium	FS	300-302	0902
11. Montane serpentine area in North Cascades	T-31	With special attention to endemic plant species; Twin Sisters Peak, Mount Baker National Forest	Low	FS	309	0703
12. Red alder forest including small stream drainage	T-10		Low	State FS		0702

See footnotes at end of table.

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Predominantly aquatic natural areas:						
13. Low-elevation lake and drainage basin of temperate forest	A-4 R&E-2,3,4,6		High	FS State		0603
14. Subalpine lake and drainage basin (without fish)	A-5 R&E-5,6,7	Findley Lake is good candidate	Medium	City of Seattle		0602
15. Subalpine lake and drainage basin (with fish)	A-8 R&E-5,6,7	If not too disturbed, Lake Twentytwo RNA may suffice	Medium	FS NPS		0703
16. Glacially fed subalpine stream and drainage	A-13 R&E-5,6,7	Possibly can fill by enlarging Boston Glacier RNA	Medium	NPS		0704
17. Large, upwelling cold spring	A-14		Low	NPS,FS State		
18. Typical hot spring	A-15		Medium	NPS,FS State		
Natural areas for protection of rare or threatened species:						
19. Subalpine meadow area focused on concentration of plant species of special interest		See table 20 for subalpine species of special interest; Mount Rainier National Park	High	NPS		0901
20. Area along Perry Creek (South Fork Stillaguamish River) for preservation of a unique assemblage of rare fern species		Species include *Asplenium trichomanes*, *Botrychium* spp., *Polystichum andersonii*, and *P. lonchitis*; Mount Baker National Forest	High	FS		0703
21. Area in the western half of the Columbia Gorge region focused on rare and endangered organisms	R&E-1	See table 20 for vascular plants of special interest in Columbia Gorge region; possible sites include Silver Star or Larch Mountains	Medium	State FS		0606

[1]For a description of these cells see table 17 for terrestrial (T) ecosystems, table 18 for aquatic (A) ecosystems, and table 19 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate those cells which are considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential components.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of the type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. FS = Forest Service, NPS = National Park Service.

[4]See appendix V.

EASTERN SLOPES PROVINCE, WASHINGTON CASCADES

This province, similar to the adjacent Western Slopes and Crest Province, has two main sections, i.e., southern and northern, with the dividing line in the Snoqualmie Pass area (fig. 1). The northern section is characterized, for the most part, by extremely steep slopes and abundant evidence of glaciation. The southern portion, on the other hand, has more subdued relief, although steep slopes are locally present, especially adjacent to major drainages.

Geologically the northern portion of the province is made up of a variety of ancient (Paleozoic to Cretaceous) sedimentary and metamorphic rocks. Generally, these have undergone considerable tectonic deformation; as a result, bedding planes are often steeply tilted. Soils in the area are generally influenced to some extent by volcanic ash and, in some areas, loess. Soil profiles reflect the drier conditions under which they were formed; and poorly developed, stony soils are common. Because of sparse vegetation and low amounts of water-stable aggregates, certain soils—especially those derived from sandstone—are subject to serious surface erosion following disturbance.

The most abundant rock type in the southern section is Miocene basalt. These lavas flowed into the province from the east and are part of the extremely widespread Columbia River basalt flows. Pleistocene to Recent volcanic ash mantles the basalt in many areas, and loess deposits are also widespread. Other parent materials include sandstone, andesite, and glacial till. Most soils in this section tend to be finer textured than those to the north, with silt loams and loams most common.

The ecosystem types on the eastern slope of Washington's Cascade Range are many and diverse. The majority of the landscape is forested; but the forests are highly varied in composition as a consequence of environmental variation and disturbances, particularly fire (Franklin and Dyrness 1973). At low- to mid-elevations, mixed forests are dominated by ponderosa pine, Douglas-fir, grand fir, western larch, and lodgepole pine. At higher elevations, subalpine fir and Engelmann spruce become dominants. A variety of subalpine parklands and meadow types are abundant at higher elevations. At lower elevations the forests of ponderosa pine form mosaics with grassland and sagebrush communities. These patterns reflect the increasing aridity with decreased elevation found on the lee (rain-shadow) slope of the Cascade Range. There is also a strong environmental gradient moving east from the Cascade Crest (to a drier, more continental climate) at a given elevation along major east-west secondary mountain ranges (Wenatchee, Entiat, and Chelan Mountains, for example). This gradient is also reflected in the biota of the communities. Geological substrate provides yet another contribution to diversity in this province. A unique array of communities and organisms is associated with serpentine portions of the Wenatchee Mountains.

The 21 terrestrial cells presently identified (table 23) are selected to provide minimal representation of the major forest, subalpine and alpine meadows, and shrub-steppe communities. Because of the variability in many of these broadly defined types, representation in both the northern and southern halves of the province is necessary. Eleven cells are for coniferous forests, four for subalpine and alpine mosaics, two for shrub-steppe communities, and four for other types, including serpentine vegetation.

Aquatic cells total 11 (table 24). These include a series of lakes, ponds, and vernal pools at higher elevations and montane stream drainages on normal and serpentine topography.

It is presumed that the terrestrial and aquatic cells will incorporate the normal array of plant and animal species associated with these ecosystems. Seven rare or endangered vertebrate animals have been listed as cells in Research Natural Area identification (table 25). There are a large number of vascular plants of special interest in the province (table 26); 32 of these are on the Smithsonian list as threatened and endangered. The Wenatchee Mountains, partially because of the serpentine outcrops, is the major contributor. The area around the eastern end of the Columbia River Gorge (mainly Klickitat County) also is an area where many of these rare and endangered plants are concentrated.

The job of Research Natural Area establishment has scarcely begun; only two small areas exist, both on Forest Service lands (table 27). Four cells, all terrestrial, out of a total of 39 identified for this province are filled. None of the plants of special interest are protected within Research Natural Areas; fortunately, existing and proposed Wilderness and Botanical Areas provide protection for many.

It is estimated that 21 additional Research Natural Areas are needed to provide minimal representation of the identified freshwater, terrestrial, and vertebrate animal cells, as well as several of the rare or threatened vascular plants (table 28). Three of these are relatively large drainages providing representation of widespread terrestrial and aquatic ecosystems. Eleven focus on terrestrial cells, four on special aquatic types, and three on rare and endangered vascular plants.

There is a very large job in selection and establishment of the necessary Research Natural Areas in this province. The lead responsibility clearly rests with the Forest Service (table 28). Washington State agencies, private institutions (especially along the Columbia River), and the National Park Service (because of the Lake Chelan National Recreation Area) may also have significant contributions to make in this province.

Expanding human activity at low- to mid-elevations, logging over the bulk of the province, and development near the Columbia River and urban centers make establishment of Research Natural Areas of high priority in these regions (table 28). Subalpine and alpine needs are generally of lower priority.

Table 23.--*Terrestrial cells in the Eastern Slopes Province, Washington Cascades*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Ponderosa Pine Zone:			
1. Ponderosa pine-bitterbrush community	237	Wolf Creek RNA; also proposed Boulder Creek RNA	173-175
Grand Fir and Douglas-fir Zone:			
2. Ponderosa pine-Douglas-fir/snowberry/ bunchgrass community	214	Wolf Creek RNA	191-192
* 3. Ponderosa pine-Douglas-fir/pinegrass	237	Token in Meeks Table RNA, need additional area	191-193
* 4. Mixed conifer (ponderosa pine, grand fir, Douglas-fir, western larch)/ shrub communities (*Pachistima*, snowbrush, spiraea, snowberry, oceanspray, huckleberry) in northern section on a variety of sites		None	191-192 195-199
* 5. Mixed conifer/shrub communities on a variety of sites in central section		None	191-192 195-199
* 6. Mixed conifer/shrub communities on a variety of sites in southern section		None	191-192 195-199
Western Hemlock Zone:			
* 7. Western redcedar-western hemlock forest	227	None	202-204
Subalpine forest types:			
* 8. Engelmann spruce-subalpine fir forest with some on lower slopes and cold bottom areas, including good representation of subalpine fir/*Pachistima* association	206	None	205-207
* 9. Subalpine larch forest	208	None, but would be partially filled with establishment of proposed Tiffany Mountain RNA	281
*10. Pacific silver fir forest		None	94-98

See footnote at end of table.

Table 23.--*Terrestrial cells in the Eastern Slopes Province, Washington Cascades* (Continued)

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
balpine and alpine parkland communities:			
1. Subalpine sagebrush (*Artemisia tridentata* var. *vaseyana*) parkland		None	207-208
2. Alpine community mosaic (including *Carex-Kobresia* turf)		None	284-290
3. Subalpine parkland (north section) with good east-side dry meadow types (green fescue)		None, but may be filled with establishment of proposed Tiffany Mountain RNA	250-268
4. Subalpine parkland (south section) with good east-side dry meadow types (green fescue)		None	250-268
rub-steppe communities:			
5. Bitterbrush/bunchgrass communities		Wolf Creek RNA	222-223
6. Stiff sagebrush/herb-grass community		Meeks Table RNA	201
ecial types:			
7. Mountain meadow in grand fir zone dominated by *Deschampsia*		None	199-201
8. Riparian hardwoods (black cottonwood-willow)	222	None	
9. Oregon white oak-conifer mosaic	233	None	168 171 191
0. Montane serpentine area		None, but need would be met with establishment of proposed Eldorado Creek RNA	307-309
1. Typical lodgepole pine forest	216	None	192-193 197-198

*Cells presently lacking adequate representation.

Table 24.--*Aquatic cells in the Eastern Slopes Province, Washington Cascades*

Cell[1]	Present representation	Remarks
* 1. Low-elevation eutrophic lake and drainage basin	None	
* 2. Oligotrophic lake and mixed-conifer drainage basin	None	
* 3. Low-elevation permanent ponds	None	
* 4. Mid-elevation permanent ponds	None	
* 5. Low-elevation vernal ponds	None	
* 6. Mid-elevation vernal ponds	None	
* 7. Large stream drainage with mixed-conifer forest	None	Should extend from about 3,000-5,000-foot elevation
* 8. Stream drainage in a montane serpentine area	None	
* 9. Large, upwelling cold spring	None	
*10. Typical hot spring	None	
*11. Marshland-bog area	None	

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 25.--*Rare and endangered vertebrate animal cells in the Eastern Slopes Province, Washington Cascades*

Cell	Verified representation	Reference
Reptiles:		
*1. Pacific ringnecked snake	None	Stebbins 1954
*2. Oregon alligator lizard	None	Stebbins 1954
Birds:		
*3. Cascade boreal chickadee	None	Alcorn 1971
Mammals:		
*4. Masked shrew (subspecies *cinereus*)	None	Dalquest 1948
*5. Western gray squirrel	None	Dalquest 1948
*6. Heather vole	None	Dalquest 1948 Edwards 1955 Johnson 1973 Johnson and Johnson 1952 Maser and Storm 1970 Shaw 1924
*7. Northern bog lemming	None	Dalquest 1948 Maser and Storm 1970

*Cells presently lacking adequate representation.

Table 26.--*Vascular plants of special interest in the Eastern Slopes Province, Washington Cascades*

Species[1]	Distribution
Anemone drummondii	Wenatchee Mountains on serpentine
Arabis lemmonii var. *paddoensis*	Mount Adams and probably Wenatchee Mountains
Asplenium viride	On limestone
Astragalus pulsiferae	Mount Adams and Falcon Valley
Astragalus whitneyi var. *sonneanus*	Often on serpentine
Cacaliopsis nardosmia	Typically in yellow pine stands
Calamagrostis howellii[2]	Columbia River Gorge in Klickitat County
Campanula lasiocarpa	Alpine
Carex parryiana	Wenatchee Mountains
Carex proposita	Alpine talus in Wenatchee Mountains
Cassiope tetragona	Alpine near Canadian border
Castilleja elmeri	Mainly on serpentine in Wenatchee Mountains
Ceanothus prostratus	Yakima County south
Chaenactis nevii[2]	Wenatchee Mountains
Chaenactis ramosa[2]	Only Wenatchee Mountains
Chaenactis thompsonii[2]	On serpentine, Wenatchee Mountains only
Cheilanthes feei	Limestone crevices
Claytonia megarhiza var. *nivalis*[2]	Only in Mount Stuart area of serpentine
Clematis columbiana var. *dissecta*	Wenatchee Mountains
Cryptantha thompsonii[2]	On serpentine, Wenatchee Mountains only
Cryptogramma stelleri	
Cypripedium calceolus	
Cypripedium fasciculatum	
Cypripedium montanum	Found around east end of Columbia River Gorge
Delphinium lineapetalum	Lower elevations in Wenatchee Mountains
Delphinium multiplex[2]	Along intermittent streams in yellow pine and sagebrush, Wenatchee Mountains
Delphinium viridescens[2]	Moist meadowland, Wenatchee Mountains
Delphinium xantholeucum[2]	Grassland and yellow pine, Chelan and Okanogan Counties
Douglasia nivalis var. *dentata*	Wenatchee Mountains, on serpentine
Draba aurea	
Draba oligosperma	
Eleocharis atropurpurea	Lake Chelan
Elmera racemosa	
Epipactis gigantea	
Erigeron leibergii[2]	Moderate to high elevations, Wenatchee Mountains north
Eriogonum pyrolaefolium	On serpentine in Wenatchee Mountains
Eritrichium nanum var. *elongatum*	Okanogan County
Fritillaria pudica	Sagebrush and yellow pine

See footnotes at end of table.

Table 26.--*Vascular plants of special interest in the Eastern Slopes Province, Washington Cascades* (Continued)

Species[1]	Distribution
Garrya fremontii	Eastern end Columbia River Gorge, Klickitat County
Geum rivale	Okanogan County
Geum rossii var. *depressum*	Only in Wenatchee Mountains
Habenaria orbiculata	Mid-elevation forests
Haplopappus hallii[2]	East end of Columbia River Gorge
Hedysarum sulphurescens	Okanogan County
Heuchera grossulariifolia var. *tenuifolia*	Columbia River Gorge
Hieracium longiberbe[2]	Columbia River Gorge
Hydrophyllum capitatum var. *thompsoni*[2]	Columbia River Gorge north into Yakima County
Iliamna longisepala[2]	Low-elevation Kittitas to Chelan and Douglas Counties
Iliamna rivularis	
Ivesia tweedyi[2]	Chelan to central Yakima County, often on serpentine
Lathyrus nevadensis ssp. *lanceolatus* var. *puniceus*[2]	Only in Wenatchee Mountains
Ledum glandulosum var. *columbianum*	Wet serpentine areas in Wenatchee Mountains
Lewisia tweedyi[2]	Only in Wenatchee Mountains
Linanthus bakeri	Klickitat County
Liparis loeselii	Springs and bogs, Klickitat County
Lithophragma tenella var. *thompsonii*	Okanogan, Grant, and Yakima Counties
Lomatium brandegei	Kittitas to southern Okanogan Counties
Lomatium columbianum	Klickitat County to Yakima County near Columbia River
Lomatium cuspidatum[2]	On serpentine, Kittitas and Chelan Counties
Lomatium suksdorfii[2]	Western Klickitat County
Lomatium thompsonii[2]	Wenatchee region, Chelan County
Lupinus latifolius var. *thompsonianus*	Eastern end of Columbia River Gorge
Mimulus jungermannioides[2]	Mossy mats at eastern end of Columbia River Gorge
Mimulus pulsiferae	Klickitat County
Oryzopsis hendersonii	
Parnassia kotzebuei var. *pumila*[2]	Near Gilbert, Okanogan County; possibly extinct
Pellaea glabella var. *simplex*	Columbia River Gorge
Penstemon barrettiae[2]	Eastern end of Columbia River Gorge, Klickitat County
Penstemon lyallii	Possibly near Stevens Pass

See footnotes at end of table.

Table 26.--*Vascular plants of special interest in the Eastern Slopes Province, Washington Cascades* (Continued)

Species[1]	Distribution
Penstemon subserratus[2]	Yakima, Klickitat, and eastern Skamania Counties
Penstemon washingtonensis[2]	Moderate elevations, Chelan and Okanogan Counties
Petasites warrenii[2]	Swank Creek drainage, Kittitas County; possibly extinct
Phlox hendersonii	Chelan County south
Physaria alpestris	Subalpine talus and rocky ridges, Chelan County to Mount Adams
Poa curtifolia[2]	On serpentine in subalpine and alpine Wenatchee Mountains
Polystichum californicum	Wenatchee Mountains south
Polystichum kruckebergii[2]	Mount Adams
Polystichum mohrioides	On serpentine, Kittitas and Chelan Counties
Polystichum scopulinum	Wenatchee Mountains
Salix brachycarpa	Wenatchee Mountains
Salix vestita	Chelan County
Saxifraga integrifolia var. *apetala*	Along base of Cascade Range, Okanogan to Yakima Counties
Saxifraga lyallii	Okanogan County
Saxifraga occidentalis	Disjunct in Tumwater Canyon
Saxifraga oppositifolia	
Sedum lanceolatum var. *rupicolum*	Wenatchee Mountains
Selaginella douglasii	Columbia River Gorge
Senecio elmeri	Alpine areas
Sidalcea oregana var. *calva*[2]	Only in Wenatchee Mountains
Silene seelyi[2]	Only in Wenatchee Mountains
Silene suksdorfii	Wenatchee Mountains
Spiraea pyramidata	Natural hybrid
Suksdorfia violacea	Intermittently distributed from Columbia River Gorge to Canada
Trifolium thompsonii[2]	Swakane Canyon, Chelan County
Valeriana columbiana[2]	Open slopes, eastern Wenatchee Mountains
Viola sheltonii	Disjunct near Cle Elum

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or their identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]The species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 27.--*Established Research Natural Areas in the Eastern Slopes Province, Washington Cascades*

Name	Principal features	Agency[1]	Area	
			Ha	Acres
Meeks Table RNA	Interior ponderosa pine forest on isolated butte	FS	28	68
Wolf Creek RNA	Bitterbrush and bunchgrass communities	FS	61	150

[1]FS = Forest Service.

Table 28.--*Additional Research Natural Areas needed in the Eastern Slopes Province, Washington Cascades*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic natural areas:						
1. Large stream drainage (from 3,000 to 5,000 ft) with a variety of mixed-conifer (ponderosa pine, Douglas-fir, grand fir) communities	T-4 A-7,4,6 R&E-6,7	In northern section, perhaps near Pasayten Wilderness Area or possibly in Lake Chelan National Recreation Area	High	FS NPS	191-192 195-196 202-204	0803 0806 0807
2. Oligotrophic lake and ponds; surrounding mixed-conifer drainage basin	T-5 A-2,4,6	If possible, should be located in central section	High	FS NPS	191-192 195-196	0904
3. Large stream drainage in a montane serpentine area, with a variety of endemic plant species	T-20 A-8	Need will be met with establishment of proposed Eldorado Creek RNA	High	FS	307-309	0806
Predominantly terrestrial natural areas:						
4. Ponderosa pine-Douglas-fir/pinegrass community	T-3 A-5	Chiwaukum Creek-Tumwater Canyon area, Chelan County. Also proposed Boulder Creek RNA would help fill need	Medium	FS State	191-192	0803 0805
5. Lodgepole pine forest	T-21 R&E-5	Wenatchee or Okanogan National Forests	Medium	FS	192-193 197-198	0802 0803
6. Mixed conifer (ponderosa pine, Douglas-fir, grand fir, western larch)/shrub communities in southern part of the area	T-6 R&E-4	Wenatchee National Forest (Naches or Tieton Districts)	High	FS	191-192 195-199	0902 0904
7. Subalpine fir-Engelmann spruce and Pacific silver fir forest types	T-8,10 R&E-3	Upper slope type in Wenatchee National Forest	High	FS	205-207	0802
8. Mountain meadow in grand fir zone dominated by *Deschampsia*	T-17	Select to span moisture gradient	Medium	FS	199-201	0902 0904
9. Subalpine parkland with dry meadow type (green fescue) and subalpine larch forest	T-9,14	Expansion of proposed Tiffany Mountain RNA may fill this need	Medium	FS NPS	263-264 281	0901
10. Subalpine parkland in the southern portion of the area	T-13	Wilderness Area	Low	FS NPS	250-268	0901
11. Subalpine sagebrush parkland	T-11	Swakane Canyon and Colockum are possibilities (in central portion)	Medium	FS State	207-208	0804
12. Riparian hardwoods (black cottonwood)	T-18		High	Private FWS State		

See footnotes at end of table.

Table 28.--*Additional Research Natural Areas needed in the Eastern Slopes Province, Washington Cascades* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
13. Alpine community mosaic	T-12	Wilderness area in north or central Cascades	Low	FS NPS	284-290	0804
14. Oregon white oak-conifer mosaic	T-19 R&E-1,2	Central or southern portions	Medium	State	168, 171, 191	0902 1107
Predominantly aquatic natural areas:						
15. Low-elevation eutrophic lake and ponds	A-1,3,5		High	FS State		
16. Large, upwelling cold spring	A-9		Low	FS NPS		
17. Typical hot springs	A-10		Medium	FS NPS		
18. Relatively large marsh and bog area	A-11 R&E-7	Selma Meadows	High	FS NPS		
Natural areas for protection of rare or threatened plant species:						
19. Basalt rock areas along Klickitat River for protection of the very rare *Penstemon barrettiae*		Klickitat County	High	State Private		0904
20. An area in Swakane Canyon for protection of *Trifolium thompsonii*		RNA in process of establishment	High	FS		0804
21. Area at east end of Columbia River Gorge with concentration of special-interest plant species		See table 26 for species of interest	High	State Private		

[1]For a description of these cells see table 23 for terrestrial (T) ecosystems, table 24 for aquatic (A) ecosystems, and table 25 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate those cells which are considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential components.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of the type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. FS = Forest Service, FWS = Fish and Wildlife Service, NPS = National Park Service.

[4]See appendix V.

›LUMBIA BASIN PROVINCE, WASHINGTON

The Columbia Basin is the largest province, occupying roughly two-thirds of the area east of the Cascades in Washington (fig. 1). For the most part, topography in the province ranges from gently undulating to moderately hilly; steep slopes are generally restricted to isolated volcanic buttes or stream-cut canyons. Because of the subdued relief, elevations are generally low, ranging from about 150 to 600 m.

Columbia River basalt of Miocene age underlies virtually the entire province and is the feature which geologically sets it apart from adjacent provinces. In some places these thick layers of basalt were altered during the Pleistocene by tectonic deformation or stream dissection, thus producing ridges and valleys seen today. The most outstanding example of stream-cut topography is the Channeled Scablands, located near the center of the province. This gigantic series of deeply cut channels in the basalt was apparently formed by floodwaters originating from glacial lakes during the Pleistocene.

Pliocene-Pleistocene deposits cover the Columbia River basalt over extensive tracts. The most widespread deposit is Palouse loess, a massive tan-colored silt up to 4.5 m thick, which mantles an elliptical area 160 km long in southeastern Washington. This deposit is characterized by smoothly rolling hills and soils of high fertility.

Broad soil differences in the Columbia Basin are largely correlated with differences in annual precipitation. Although the entire province is, in general, an area of low precipitation, there are substantial differences in rainfall pattern. In general, precipitation is heaviest along the margins of the basin and gradually decreases toward the central portion. Consequently soils in the Palouse Hills (near the eastern margin) are generally deep, well-developed Prairie or Chernozem soils, formed under grassland vegetation. Typically they have a thick, dark-colored silt loam A horizon, underlain by a silty clay loam B horizon which lacks a zone of calcium carbonate accumulation. Adjacent to this zone at lower elevations are Chestnut soils, which reflect the more arid conditions. These soils have a moderately thick, brown silt loam A horizon and a poorly developed silt loam B horizon which includes a zone of calcium carbonate accumulation. In the central portion of the province, arid conditions prevail and, as a result, desertic soils predominate. Here the most common soils are Sierozems. These have thin, light-colored A horizons over clay-enriched B horizons containing a layer of calcium carbonate which is often cemented.

Steppe and shrub-steppe ecosystems typify the undeveloped lands of the Columbia Basin (Franklin and Dyrness 1973). Big sagebrush-bunchgrass and bunchgrass communities dominate the western and central portions of the basin, with forb-rich meadow steppe characteristic of the northern and eastern margins. Unusual soil conditions, such as the shallow soils associated with scablands, are sites occupied by a large array of distinctive shrub-bunchgrass communities, many dwarfed in stature. Areas of saline and alkali accumulations, riparian habitats, cliffs and scree slopes, and dunes add further to the diversity. Finally, ponderosa pine and quaking aspen communities intrude along the margins and canyons of the province.

Aquatic ecosystems are more abundant than might be expected in this arid province. They consist largely of ponds, lakes, vernal pools, and marshes of varying chemistry, many of them in channeled scablands. Streams are relatively uncommon.

Terrestrial cells which have been identified total 43 (table 29). This reflects several factors, including the large size and diversity of the province and the greater detailed knowledge of its ecosystems, largely because of the work of R. Daubenmire. Included are cells for all of the distinctive plant associations he has identified—ponderosa pine forest and various types of steppe, shrub-steppe, and meadow steppe including zonal types as well as communities found on specialized habitats.

Identified aquatic cells total 13 (table 30). There is a special need for a series of ponds and lakes representing a chemical gradient from freshwater to saline and alkali. A widespread and important new type of aquatic ecosystem associated with irrigation projects, "wasteways and potholes" (No. 13), is included in the list.

It is assumed that the various aquatic and terrestrial Research Natural Areas will incorporate the fauna and flora typical of these ecosystem types. Twelve rare or endangered animals are listed (table 31) for special consideration as cells in selecting and establishing Research Natural Areas. This relatively large number is because of the widespread conversion of most of the province to agricultural production and consequent loss of habitats for many species. There is also a relatively large number of vascular plants of special interest (table 32). A large proportion of these are on the Smithsonian list of threatened and endangered plants (20 species), again reflecting a loss of habitat to agricultural and other developments, especially in the Palouse region.

Three Research Natural Areas and two preserves created through The Nature Conservancy presently exist in the Columbia Basin (table 33). Fortunately one of these—Rattlesnake Hills—is very large and includes many representative ecosystem types. Even so, only 11 of the 68 terrestrial, aquatic, and rare and endangered cells identified for the province have been filled. These fill 7 cells out of 43 terrestrial, 2 out of 13 aquatic, and 2 out of 12 vertebrate animal cells listed.

It was suggested at the workshop that 12 additional Research Natural Areas could provide for minimal representation of the remaining 57 cells (table 34). Considering the scarcity of large areas with natural or near-natural ecosystems and the large number and diversity of cells to be filled, this seems extremely optimistic (as several reviewers have pointed out). It is likely that more than 12 Research Natural Areas will be necessary, particularly if they are small. However, we have decided to leave the listing of remaining natural area needs as it is in the absence of better knowledge on how cells could be aggregated. Consequently, the reader should be particularly sensitive in this province to filling cellular needs (tables 29-31) rather than trying to locate tracts which meet all of the listed characteristics for the tentative and highly diverse Research Natural Areas in table 34 (for example, Nos. 1-4, 6, and 9).

In any case a very large job of natural area preservation exists in the Columbia Basin, and lead responsibility is probably more diverse than in most (table 34). State agencies and institutions, private organizations, and Fish and Wildlife Service have particularly large responsibilities but would be assisted by Bureau of Land Management, Energy Research and Development Administration, and Bureau of Reclamation, among others. Priorities are uniformly high because of rapid expansion of human developments in this already extensively altered province. Completion of the Research Natural Area system in the Columbia Basin may prove very difficult, not only because of rapid, large-scale conversion of natural communities to agricultural uses but also because of the large number of cells to be filled. The province should receive major emphasis from State and private groups.

Table 29.--*Terrestrial cells in the Columbia Basin Province, Washington*

	Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Ponderosa pine communities:				
1.	Ponderosa pine/Idaho fescue community	237	Turnbull Pine and Pine Creek RNA's	173-175
* 2.	Ponderosa pine/ninebark community	237	None	173-175
* 3.	Ponderosa pine/snowberry community	237	Some representation at Turnbull Pine RNA, need additional area	173-175
* 4.	Ponderosa pine/bluebunch wheatgrass community	237	None	173-175
* 5.	Ponderosa pine/needlegrass community	237	None	173-175
Zonal meadow-steppe associations:				
6.	*Festuca idahoensis/Symphoricarpos albus* community		Washington State University preserves	211-216 220-222
* 7.	*Artemisia tripartita/Festuca idahoensis* community		None	211-216 222
* 8.	*Festuca idahoensis/Hieracium cynoglossoides* community		None	211 224
* 9.	*Purshia tridentata/Festuca idahoensis* community		None	211-216 222-223
*10.	*Festuca idahoensis/Rosa nutkana* community		None	211 224
*11.	*Purshia tridentata/Agropyron spicatum* community		None	223
Zonal steppe associations:				
*12.	*Artemisia tridentata/Agropyron spicatum* community		Well represented in Rattlesnake Hills RNA, need additional examples elsewhere	211-218
*13.	*Artemisia tridentata/Festuca idahoensis* community		None	211-216 219
*14.	*Agropyron spicatum-Poa sandbergii* community		None	211-216 225-227
*15.	*Agropyron spicatum-Festuca idahoensis* community		None	211-216 219-220

See footnote at end of table.

Table 29.--*Terrestrial cells in the Columbia Basin Province, Washington* (Continued)

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Stipa comata associations on deep gravelly or sandy soils:			
*16. *Artemisia tridentata/Stipa comata* community		None	224-225
*17. *Purshia tridentata/Stipa comata* community		None	224-225
*18. *Stipa comata-Poa sandbergii* community		None	224-225
*19. *Artemisia tripartita/Stipa comata* community		None	224-225
Associations on shallow soils:			
20. *Eriogonum douglasii/Poa sandbergii* community		Rattlesnake Hills RNA	224-225
*21. *Artemisia rigida/Poa sandbergii* community		None	225-227
*22. *Eriogonum niveum/Poa sandbergii*		None	225-227
*23. *Eriogonum sphaerocephalum/Poa sandbergii* community		None	225-227
*24. *Eriogonum compositum/Poa sandbergii* community		None	225-227
*25. *Eriogonum thymoides/Poa sandbergii* community		None	225-227
*26. *Eriogonum microthecum-Physaria oregana* community		None	225-227
*27. Lithosolic *Agropyron spicatum-Poa sandbergii* community		Some in Washington State University preserve, need additional area	225-227
Dry site shrub/*Poa* associations:			
28. *Artemisia tridentata/Poa sandbergii* community		Rattlesnake Hills RNA	228
29. *Grayia spinosa/Poa sandbergii* community		Rattlesnake Hills RNA	228
30. *Eurotia lanata/Poa sandbergii* community		Rattlesnake Hills RNA	228

See footnote at end of table.

Table 29.--*Terrestrial cells in the Columbia Basin Province, Washington* (Continued)

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Distichlis stricta associations on saline and alkali soils:			
*31. *Distichlis stricta* communities		None	227
*32. *Elymus cinereus-Distichlis stricta* community		None	227
*33. *Sarcobatus vermiculatus-Distichlis stricta* community		None	227
Crataegus associations and related riparian types:			
*34. *Crataegus douglasii/Symphoricarpos albus* community		Small amount in Washington State University preserves, need additional area	227-228
*35. *Crataegus doublasii/Heracleum lanatum* community		None	227-228
*36. Riparian woodland with black cottonwood and white alder		None	228
Associations on specialized habitats (including colluvium and talus):			
*37. *Sporobolus cryptandrus-Poa sandbergii* community		None	228-229
*38. *Aristida longiseta-Poa sandbergii* community		None	228-229
*39. *Rhus glabra* community		None	229-230
*40. *Celtis douglasii/Bromus tectorum* community		None	229-230
*41. Basaltic talus slopes		Some in Rattlesnake Hills RNA, need additional area	229-230
42. Quaking aspen type	217	Turnbull Pine and Pine Creek RNA's	228
*43. Columbia River sand dunes in various stages of stabilization		None	230-231

*Cells presently lacking adequate representation.

Table 30.--*Aquatic cells in the Columbia Basin Province, Washington*

Cell[1]	Present representation
* 1. Freshwater lake	None
* 2. Alkaline lake	None
* 3. Saline lake	None
* 4. Freshwater permanent ponds	None
* 5. Alkaline permanent ponds	None
* 6. Saline permanent ponds	None
* 7. Typical vernal ponds	None
8. Large stream drainage in steppe and shrub-steppe vegetation	Rattlesnake Hills RNA
9. Large, cold springs	Rattlesnake Hills RNA
*10. Typical hot springs	None
*11. Freshwater marsh area	None
*12. Saline marsh area	None
*13. Wasteways and potholes	None

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 31.--*Rare and endangered vertebrate animal cells in the Columbia Basin Province, Washington*

Cell	Verified representation	Reference
Amphibians:		
* 1. Woodhouse toad	None	Stebbins 1954
Reptiles:		
* 2. Striped whipsnake	None	Stebbins 1954
* 3. Night snake	None	Stebbins 1954
Birds:		
4. Western burrowing owl	Rattlesnake Hills RNA	Alcorn 1971
Mammals:		
* 5. Merriam shrew	None	Dalquest 1948 Johnson and Clanton 1954
* 6. Pygmy rabbit	None	Dalquest 1948
* 7. White-tailed jack rabbit	None	Dalquest 1948
* 8. Washington ground squirrel	None	Dalquest 1948
* 9. Ord kangaroo rat	None	Dalquest 1948 Broadbooks 1969
10. Northern grasshopper mouse	Rattlesnake Hills RNA	Dalquest 1948
*11. Kinkaid meadow vole	None	Dalquest 1948 Maser and Storm 1970
12. Sagebrush vole	Rattlesnake Hills RNA	Clanton et al. 1971 Dalquest 1948 Johnson et al. 1948 Maser et al. 1974 Maser and Storm 1970 O'Farrell 1972

*Cells presently lacking adequate representation.

Table 32.--*Vascular plants of special interest in the Columbia Basin Province, Washington*

Species[1]	Distribution
Allium robinsonii[2]	Along Columbia River, Vantage to John Day River
Angelica canbyi	General in province
Antennaria parvifolia	Disjunct from Great Plains
Aster jessicae[2]	Palouse region
Astragalus columbianus[2]	Probably extinct; at Priest's Rapids
Astragalus diaphanus	Along Columbia River, Klickitat County
Astragalus kentrophyta var. *douglasii*[2]	Around Walla Walla with sagebrush
Astragalus leibergii	Douglas, Chelan, and Kittitas Counties with sagebrush
Astragalus pulsiferae	Falcon Valley, Klickitat County
Astragalus riparius	Lower Snake River, Whitman and Columbia Counties
Astragalus sinuatus[2]	Along Colockum Creek, Chelan County
Astragalus speirocarpus	Near Columbia River in lower Columbia Basin with sagebrush
Astragalus succumbens	Klickitat and Grant Counties, with sagebrush
Astragalus tweedyi	Lower Columbia Basin with sagebrush
Balsamorhiza hirsuta	Between Ellensburg and Yakima
Balsamorhiza rosea[2]	Widely disjunct in basin; protected in Rattlesnake Hills RNA
Bolandra oregana	Moist mossy areas along Snake River
Calochortus nitidus[2]	Palouse region
Castilleja thompsonii	Sagebrush associate
Chaenactis douglasii var. *glandulosa*	Along Snake River
Cirsium brevifolium[2]	Palouse region
Collinsia sparsiflora	Lower Columbia River
Crepis modocensis ssp. *glareosa*	Around Ellensburg
Cryptantha fendleri	Franklin County
Cryptantha leucophaea	Along Columbia River from Wenatchee to The Dalles
Delphinium depauperatum	Moist areas in sagebrush valleys, Asotin County
Dicentra cucullaria	Sandy banks along Columbia River
Erigeron basalticus	Crevices in rocky canyons, Yakima County
Erigeron piperianus	With sagebrush
Eriogonum angulosum	Yakima County (disjunct from southeastern Oregon)
Eriogonum thymoides	With sagebrush
Hackelia arida	Western half of basin
Hackelia cinerea	Kittitas and Chelan Counties
Hackelia hispida[2]	Grand Coulee and Snake River
Hackelia venusta[2]	Chelan County

See footnotes at end of table.

Table 32.--*Vascular plants of special interest in the Columbia Basin Province, Washington* (Continued)

Species[1]	Distribution
Haplopappus liatriformis[2]	Palouse region
Helianthus cusickii	Western basin north to Ellensburg
Iliamna longisepala[2]	Kittitas to Chelan and Douglas Counties
Lathyrus bijugatus[2]	Palouse region
Lomatium salmoniflorum	Palouse region
Lomatium tuberosum[2]	Fort Simcoe-White Swan area
Lomatium watsonii	Kittitas County south
Lupinus sericeus var. *asotinensis*	Asotin and Whitman Counties
Marsilea vestita	Mud of lakes and vernal pools
Mimulus clivicola	Upper Snake River
Mimulus washingtonensis	Wet, open areas, Klickitat County
Navarretia tagetina	Mouth of Klickitat River
Oenothera flava	Along Yakima River
Oryzopsis hendersonii	Yakima and southern Kittitas Counties
Pediocactus simpsonii	Widespread but much collected
Penstemon deustus var. *variabilis*	Klickitat County
Penstemon eriantherus var. *whitedii*	Chelan and Douglas Counties
Penstemon gairdneri var. *gairdneri*	Scablands, northeastern basin
Petrophytum cinerascens[2]	Basalt cliffs along Columbia River, Chelan County
Polemonium pectinatum[2]	Moist bottomlands, Whitman and Spokane Counties
Ranunculus reconditus[2]	Sagebrush slopes, Klickitat County
Ribes cereum var. *colubrinum*	Along Snake River, Asotin County
Rubus nigerrimus[2]	Snake River Canyon, Whitman County
Salix drummondiana	Palouse region
Scirpus olneyi	Grant County
Silene spaldingii[2]	Palouse region; found in Washington State University steppe preserve
Synthyris missurica	Palouse region
Talinum spinescens	Scablands
Tauschia hooveri[2]	Scablands, Yakima County
Tragopogon mirus	Near Pullman and Palouse
Tragopogon miscellus	Palouse region

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or their identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]The species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 33.--*Established Research Natural Areas in the Columbia Basin Province, Washington*

Name	Principal features	Agency[1]	Area	
			Ha	Acres
Moxee Bog Preserve	Floating sphagnum bog in steppe region of Yakima County	YCC	6	14
Pine Creek RNA	Interior ponderosa pine and grasslands	FWS	65	160
Rattlesnake Hills RNA	Dry Columbia Basin shrub steppe	ERDA	30 364	75,000
Rose Creek Preserve	Seminatural grassland and shrub communities in Palouse region	TNC	5	12
Turnbull Pine RNA	Interior ponderosa pine, grassland, and ponds	FWS	81	200

[1]ERDA = Energy Research and Development Administration, FWS = Fish and Wildlife Service, TNC = The Nature Conservancy, YCC = Yakima Community College.

Table 34.--*Additional Research Natural Areas needed in the Columbia Basin Province, Washington*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Predominantly terrestrial natural areas:						
1. Large area with big sagebrush/ bunchgrass communities but also with *Artemisia tripartita*, *Artemisia rigida*, and other communities	T-7,12,13,19, 20,21,22, 23,24,25, 26,28 A-7 R&E-1,2,3,4, 5,6,7,9, 10,12	Okanogan foothills, northeast of Spokane	High	FWS BLM State FS	211-219 222 226-227	1003 1104
2. Bunchgrass communities (*Agropyron spicatum*, *Festuca idahoensis*) in the Palouse Hills	T-8,10,14,15, 6 A-7	Mostly private, so may have to be a Nature Conservancy Area	High	Private	219-224	1105
3. Bunchgrass, *Stipa comata*, and *Eriogonum* communities in an area near Moses Lake	T-16,17,18,22, 23,24,25,26, 27,12,13,14, 15 A-7 R&E-11	Should span moist to dry sites	High	BR State	224-227	1102 1104
4. Alkali saltgrass, greasewood, and giant wildrye-dominated communities on saline-alkali soils	T-31,32,33, 29,30 A-7	Banks Lake area	High	BR	227	1108
5. Riparian woodland (black cottonwood and white alder) and *Crataegus douglasii* communities	T-34,35,36	Foothills of Okanogan Uplands; strip should be 1/8-mile wide	High	FWS FS BLM	227-228	1103 1104
6. *Sporobolus cryptandrus*, *Aristida longiseta*, *Rhus glabra*, and *Crataegus douglasii* communities with a 1,000-foot elevational range	T-34,35,37 39,38	Imnaha area; Asotin, Washington, and southward	Medium	FS	227-229	1203
7. Basalt talus area	T-41	Possible this may be found in another area	Low	BR BLM ERDA	229-230	1101 1103 1104

See footnotes at end of table.

Table 34.--*Additional Research Natural Areas needed in the Columbia Basin Province, Washington* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
8. Area of Columbia River sand dunes, including dunes in various stages of stabilization	T-43		High	BLM State	230-231	1110
9. Area with a variety of ponderosa pine communities on both north and south slopes. In addition, should include bitterbrush/Idaho fescue and bitterbrush/bluebunch wheatgrass communities	T-1,2,3,4 5,9,11		High	Private BLM State	173-176 222-223	1106 1107
Predominantly aquatic natural areas:						
10. Scabland lakes and ponds with water quality ranging from fresh to saline in a matrix of bunchgrass or shrub-steppe vegetation	A-1,2,3,4 5,6,11, 12	Should include 6 to 10 lakes. Spokane or Sprague, Washington, area	High	FWS State		1104
11. Typical hot springs	A-10		Medium	BR Private FWS		
12. Wasteways and potholes area	A-13 R&E-8	Areas result from damming and irrigation activities	Medium	BR		1102

[1]For a description of these cells see table 29 for terrestrial (T) ecosystems, table 30 for aquatic (A) ecosystems, and table 31 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate those cells which are considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential components.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of the type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. BLM = Bureau of Land Management, BR = Bureau of Reclamation, ERDA = Energy Research and Development Administration, FS = Forest Service, FWS = Fish and Wildlife Service.

[4]See appendix V.

ANOGAN HIGHLANDS PROVINCE, RTHEASTERN WASHINGTON

The Okanogan Highlands Province (fig. 1) is essentially a high plateau area, situated at elevations of 1200 to 2400 m, which is interrupted at intervals by a series of broad valleys containing south-flowing rivers (the Okanogan, Sanpoil, Columbia, Colville, and Pend Oreille Rivers). The upland areas are characterized by generally moderate slopes and broad, rounded summits. The area east of the Columbia River is generally considered to be a part of the Rocky Mountain system, and here slopes tend to be somewhat steeper.

Virtually the entire province was repeatedly covered by glacial ice during the Pleistocene. As a result, deposits of glacial drift are found throughout the area and are especially abundant in the eastern section (north of Spokane). The province contains an almost bewildering variety of rock types, ranging in age from Precambrian to late Tertiary. The oldest rock types are concentrated in the eastern, or Rocky Mountain, section of the province and include phyllite, quartzite, graywacke, slate, and argillite. Granitic rocks of Mesozoic age occupy most of the area in the western portion. Younger sedimentary rocks of Tertiary age are largely confined to areas adjacent to main river valleys.

The soil pattern in the Okanogan Highlands is closely tied to elevation. In the mountainous areas away from the major river valleys, forested soils derived from granitic parent materials tend to have shallow, coarse-textured (gravelly sandy loam), poorly developed profiles. Soils developed on glacial drift at comparable elevations are often influenced by aerially deposited volcanic ash and therefore tend to be deeper and considerably finer textured. At lower elevations, along the margins of river valleys, soils reflect the drier climate and transitional forest-grassland vegetation. Here, well-developed Chernozem soils have developed in glacial till parent materials. These are deep, productive soils with at least moderately thick, dark-colored A horizons.

Forest ecosystems dominate the landscape of the Okanogan Highlands. Many of the ecosystems are characteristic of the Rocky Mountains (Franklin and Dyrness 1973), reflecting the more continental climatic regime; as we have defined the province, it does, in fact, include some western outliers of the Rocky Mountain system in extreme northeastern Washington (fig. 1). Ponderosa pine, Douglas-fir, western larch, and lodgepole pine are characteristic forest dominants in low- to mid-elevations and Engelmann spruce, subalpine fir, and lodgepole pine at higher elevations. Grassland or shrub communities merge into forests at lower elevations and occur as openings in a forest matrix elsewhere. Subalpine and alpine meadow types occur at higher elevations.

Twenty-seven terrestrial cells have been identified which provide minimal coverage of the major forest ecosystems and three associated meadow types (table 35). These include all the major forest communities which have been identified in the province. Forest ecosystem cells span the ponderosa pine, Douglas-fir, grand fir, western redcedar-western hemlock, and subalpine fir forest zones.

There are 11 identified aquatic cells (table 36). Most of these result from a need for lake, pond, vernal pool, and stream representation in both low-elevation and subalpine environments.

It is assumed that Research Natural Areas established to fill terrestrial and aquatic cells will include the complement of typical plant and animal species. Three vertebrate animal cells are identified for special consideration as rare and endangered species (table 37). Vascular plants of special interest include four species from the Smithsonian list of threatened and endangered plants (table 38). A number of species listed in table 38 are boreal species finding their southern limits in the Okanogan Highlands.

There are three Research Natural Areas already established in the Okanogan Highlands (table 39). These provide coverage for 7 of the 41 cells presently identified in the province.

Our present estimate is that 13 additional Research Natural Areas will provide for minimal representation of the terrestrial, aquatic, and animal cells (table 40). Although the number is small, three of the areas could be relatively large, since they must include entire drainage basins and fill several terrestrial and aquatic cells.

Lead responsibility falls heavily on the Fish and Wildlife Service, the Forest Service, and Bureau of Land Management. The State of Washington may also contribute significantly in this province.

Table 35.--*Terrestrial cells in the Okanogan Highlands Province, northeastern Washington*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Ponderosa Pine Zone:			
*1. Ponderosa pine/bluebunch wheatgrass community	237	Token in Baird Basin RNA, need additional area	173-176
*2. Ponderosa pine/Idaho fescue community	237	Token in Baird Basin RNA, need additional area	173-175
*3. Ponderosa pine/*Stipa comata* community	237	None	173-175
*4. Ponderosa pine/snowberry community	237	None	173-175
*5. Ponderosa pine/ninebark community	237	None	173-175
*6. Ponderosa pine/bitterbrush community	237	None	173-179
Douglas-fir Zone:			
*7. Ponderosa pine/pinegrass community	237	None	175-176
*8. Douglas-fir/pinegrass community, including the bearberry phase	210	Token in Maitlen Creek RNA, need additional area	191-192
*9. Douglas-fir/snowberry community	210 212 214	None	191-192
10. Douglas-fir/ninebark community	210 212 214	Maitlen Creek and Baird Basin RNA's	192
*11. Typical western larch forest	212 or 213	Token in Baird Basin RNA, need additional area	198
Grand Fir Zone:			
*12. Grand fir/Oregon boxwood community	213	Token in Maitlen Creek RNA, need additional area	195 198

See footnote at end of table.

Table 35.--*Terrestrial cells in the Okanogan Highlands Province, northeastern Washington* (Continued)

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Western Redcedar-Western Hemlock Zone:			
13. Western hemlock/Oregon boxwood community	227	Salmo RNA and token in Maitlen Creek RNA	202
*14. Western redcedar/Oregon boxwood community	228	None	202 204
15. Western redcedar/devilsclub community	228	Salmo RNA	202
16. Typical western white pine forest	215	Salmo RNA	202
Subalpine Fir Zone:			
*17. Subalpine fir/Oregon boxwood community	206	Token in Maitlen Creek RNA, need additional area	207
*18. Subalpine fir/beargrass community	206	None	205
19. Subalpine fir/rustyleaf (*Menziesia ferruginea*) community	206	Salmo RNA and token in Maitlen Creek RNA	205
*20. Subalpine fir/grouse huckleberry (*Vaccinium scoparium*) community	206	None	205-207
*21. Typical whitebark pine-subalpine fir forest	208	None	205-206
Special types:			
*22. Typical lodgepole pine forest	218	Token in Baird Basin RNA, need additional area	192 197-198
*23. Quaking aspen stands	217	None	184 193
*24. Poplar-birch (including *Cornus cornuta)*	203	None	
*25. Idaho fescue-*Eriogonum* openings in a forest area		None	
*26. Typical south-slope bald (including *Festuca viridula* and *Xerophyllum tenax)*		None	207-208
*27. High-elevation mountain meadow and associated bogs		None	207-208

*Cells presently lacking adequate representation.

Table 36.--*Aquatic cells in the Okanogan Highlands Province, northeastern Washington*

Cell[1]	Present representation
* 1. Lake and drainage basin in mixed-conifer forest	None
* 2. Subalpine lake with spruce-fir drainage basin	None
* 3. Low-elevation permanent ponds	None
* 4. Subalpine permanent ponds	None
* 5. Low-elevation vernal ponds	None
* 6. Subalpine vernal ponds	None
7. Stream drainage with mixed-conifer forest	Maitlen Creek RNA
8. Stream drainage with subalpine spruce-fir forest	Salmo RNA
* 9. Typical large cold spring	None
*10. Marsh area	None
*11. Typical bog	None

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 37.--*Rare and endangered vertebrate animal cells in the Okanogan Highlands Province, northeastern Washington*

Cell	Verified representation	Reference
Mammals:		
*1. Masked shrew (subspecies *cinereus*)	None	Dalquest 1948
*2. Pygmy shrew	None	Dalquest 1948
*3. Northern bog lemming	None	Dalquest 1948 Maser and Storm 1970

*Cells presently lacking adequate representation.

Table 38.--*Vascular plants of special interest in the Okanogan Highlands Province, northeastern Washington*

Species[1]	Distribution
Carex backii	Okanogan County
Cassiope tetragona	High elevations, Okanogan County
Castilleja cervina	
Chrysosplenium tetrandum	Southern limit in Okanogan County
Comandra livida	Often near bogs
Cryptogramma stelleri	
Delphinium xantholeucum[2]	Grasslands and yellow pine, Okanogan County
Dryas drummondii	Pend Oreille County
Erigeron leibergii[2]	Moderate to high elevations, Okanogan County
Geum rivale	Southern limit in Okanogan County
Lathyrus ochroleucus	Northeastern Washington
Listera borealis	Southern limit in Okanogan County
Lobelia kalmii	Peat bogs and shores in northeastern Washington
Lomatium orogenioides	Meadows and moist bottomlands in northeastern Washington
Lupinus lepidus var. *cusickii*	Disjunct in Okanogan County
Lupinus sulphureus var. *sulphureus*	Okanogan County
Parnassia kotzebuei pumila[2]	Near Gilbert, Okanogan County, possibly extinct
Penstemon lyallii	Spokane County
Penstemon washingtonensis[2]	Moderate elevations, Okanogan County
Petasites sagittatus	Northeastern Washington
Physaria didymocarpa	Stevens County and east
Talinum okanoganense	Only in Okanogan County and adjacent Canada
Thalictrum dasycarpum	Northeastern Washington
Viola renifolia	Southern limit in Okanogan County

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or their identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]Species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 39.--*Established Research Natural Areas in the Okanogan Highlands Province, northeastern Washington*

Name	Principal features	Agency[1]	Area: Ha	Area: Acres
Baird Basin RNA	Interior ponderosa pine, larch and Douglas-fir	FWS	65	160
Maitlen Creek RNA	Douglas-fir/ ninebark forest with stream drainage	FS	259	640
Salmo RNA	Interior subalpine fir and western hemlock-western redcedar forest with stream drainage	FS	563	1,390

[1]FS = Forest Service, FWS = Fish and Wildlife Service.

Table 40.--*Additional Research Natural Areas needed in the Okanogan Highlands Province, Washington*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic natural areas:						
1. Lake and drainage basin supporting mixed conifer (ponderosa pine, Douglas-fir, western larch/shrub) communities	T-4,5,9, 11,10 A-1,3,5,10	Little Pend Oreille National Wildlife Refuge	High	FWS BLM	191-192 195-199	1003 1004
2. High-elevation lake and drainage basin supporting subalpine fir/shrub communities	T-17,20,19 A-2,4,6 R&E-1,2	Wilderness Area	Medium	FS	205-207	1003 1004
3. High-elevation mountain meadow and bog	T-27 A-11 R&E-3	Bunchgrass Meadows (area also contains rare plants)	High	FS	207-208	1003 1004
Predominantly terrestrial natural areas:						
4. A variety of ponderosa pine/grass communities in a forest-steppe ecotonal area	T-1,2,3, 25,6		Medium	FS FWS	173-175 220-222	1001 1005
5. Ponderosa pine-Douglas-fir/pinegrass communities	T-7,8,11	Sherman Creek	Medium	FS	175-176 191-192	1001 1005
6. High-elevation subalpine fir and whitebark pine-subalpine fir forest, including a south-slope bald	T-18,21,26	Round Top Mountain	High	FS	205-208	1003 1004
7. Western redcedar/Oregon boxwood community	T-14,13,15	Vicinity of Hooknose Mountain	Medium	FS	202 204	1003

See footnotes at end of table.

Table 40.--*Additional Research Natural Areas needed in the Okanogan Highlands Province, Washington* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
8. Grand fir/Oregon boxwood community	T-12		Medium	FS FWS	195 198	1003 1004
9. Ponderosa pine/bitterbrush community	T-6,1,2		Medium	FS FWS	173-179	1001 1005
10. Lodgepole pine forest	T-22		Medium	FS	192 197-198	1003 1004
11. Quaking aspen stands	T-23	Little Pend Oreille National Wildlife Refuge	Medium	FWS State BLM	184 193	1001 1003
12. Poplar-birch (including *Cornus cornuta)*	T-24	Along Pend Oreille River north of Metaline Falls	Medium	FS BLM		1001
Predominantly aquatic natural areas:						
13. Typical large, upwelling cold spring	A-9		High	FS FWS BLM		

[1]For a description of these cells see table 35 for terrestrial (T) ecosystems, table 36 for aquatic (A) ecosystems, and table 37 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate those cells which are considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential components.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of the type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. BLM = Bureau of Land Management, FS = Forest Service, FWS = Fish and Wildlife Service.

[4]See appendix V.

REGON COAST RANGES PROVINCE

The southern section of the Oregon Coast Ranges Province (fig. 1) is topographically mature, with extremely steep slopes and sharp ridges. However, with the exception of the areas drained by the Wilson and Trask Rivers, the proportion of steep slopes decreases in the northern section. Mountain passes are generally located on the eastern border of the range due to faster rates of headward erosion by the numerous westward-flowing streams. Elevations of main ridge summits in the province range from about 450 to 750 m. Scattered peaks, often capped with intrusive igneous rocks, rise well above surrounding ridges.

By far the dominant rock type in the southern section of the province is tuffaceous marine sandstone, which was laid down during the Eocene. Other rock types which are locally present include scattered igneous intrusions (Oligocene) and basalt headlands along the coast (Miocene). On forested steep slopes, soils derived from sandstone are generally shallow, stony loam textured, and brown to yellowish brown in color. On more gentle slopes and ridgetops, these sandstone parent materials give rise to deep, productive soils with well-developed profiles which are dominantly silt loam to silty clay loam in texture.

The northern section of the province is underlain by about equal amounts of basalt and sedimentary rocks (sandstone and siltstone). The sedimentaries are, for the most part, of Oligocene and Eocene age, while the major portion of the basalt is dated as Miocene. Here also, soil characteristics are closely related to topography as well as to parent material. On moderate upland slopes, soils derived from basalt tend to be deep, well-aggregated, and very productive for tree growth. These are reddish-brown in color and almost free of stones; surface textures are generally clay loam and the subsoil, a silty clay loam.

The province is a heavily forested region dominated by Douglas-fir, western hemlock, Sitka spruce, and other coniferous and hardwood tree species (Franklin and Dyrness 1973). There is, nonetheless, considerable diversity even in forest ecosystem types as a consequence of major climatic gradients, local environmental differences, and historical disturbances, especially by fire and logging. Ecosystems with Sitka spruce characterize the fog belt immediately adjacent to the coast, an array of Douglas-fir and western hemlock types occupy the bulk of the mountains, and drier forest communities become more common on the lower eastern slopes of the Coast Ranges. On a few higher peaks, subalpine forests of true firs occur. Extensive wildfires initiated numerous second-growth stands of conifers now 100 to 150 years old, and logging has converted much of the original forest to young stands of red alder and conifers.

Habitats along the edge of the Pacific Ocean contribute a great deal of the province's ecological diversity. Because of the varied and distinctive character, some reviewers suggested creating a separate province for these. Included are the dune ecosystems of both the central and northern coast and headland communities.

Aquatic ecosystems are mainly streams and rivers, swamps, and marshes with relatively few lakes and ponds. Anadromous fishes are important biologic features of many river and stream systems.

Terrestrial cells identified for the Oregon Coast Ranges total 23 (table 41). Fifteen of these are for coniferous forest ecosystems including geographic (north and south) representation of particularly important, widespread types. Younger examples of Douglas-fir forest as well as old growth need to be represented. The remaining cells are for dune, headland, riparian, and mountain meadow ecosystems, as well as red alder forest.

Identified aquatic cells total 13 (table 42). Five cells are for forested stream systems, two of which should contain anadromous fish. Three cells identify needs for a lake and ponds in coastal sand dune areas. A low-elevation inland lake, swamp, bog, and marshes complete the aquatic listing.

Animals and plants of special interest are listed in tables 43 and 44. There are four rare or endangered vertebrate animals identified as cells. Vascular plants of special interest fall mainly into two groups: species found on a few isolated peaks (notably Saddle and Sugarloaf Mountains and Onion Peak, all in Clatsop County) and species found in the coastal strip immediately adjacent to the ocean. Eleven of these vascular plants are on the Smithsonian list as threatened or endangered species.

There are presently two Federal Research Natural Areas and one Nature Conservancy reserve within the Oregon Coast Ranges (table 45). These tracts fill 5 of the 40 cells listed for this province; all of the filled cells are terrestrial.

It appears that 15 additional Research Natural Areas will be necessary to provide for minimal representation of the 35 unfilled terrestrial, aquatic, and vertebrate animal cells in the province (table 46). Six of the areas needed combine major terrestrial and aquatic cells, and three of these—two stream drainages with anadromous fish and a coastal dune mosaic—are of particular significance.

Conflicts with other resource values are frequently high in this province, much of it has been altered by human developments, and private lands dominate. Consequently, the task of completing the Research Natural Area system is large. Forest Service, Oregon State agencies, and Bureau of Land Management appear to have major responsibilities, but help from the private sector will probably be needed in the acquisition of several tracts. Priorities are generally high since many of these ecosystems are being rapidly committed to logging or incompatible recreational uses.

Table 41.--*Terrestrial cells in the Oregon Coast Ranges Province*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Sitka Spruce Zone:			
*1. Sitka spruce/salal community on ocean front	223	None	59-60, 291
*2. Lodgepole pine/salal community on ocean front		None	59-60, 291
3. Sitka spruce-western hemlock/swordfern community	223	Neskowin Crest RNA (recommend enlarging to provide more diversity)	59-61
Western Hemlock Zone:			
* 4. Western hemlock/swordfern in central to northern portion	224	None	79-80
5. Western hemlock/swordfern in southern portion	224	Cherry Creek RNA	79-80
* 6. Old-growth Douglas-fir-western hemlock/swordfern in central to northern portion	230	None	79-80
7. Old-growth Douglas-fir-western hemlock/swordfern in southern portion	230	Cherry Creek RNA	79-80
* 8. Old-growth Douglas-fir-western hemlock/rhododendron/Oregongrape in central to northern portion	230	None	79-80
9. Old-growth Douglas-fir-western hemlock/rhododendron/Oregongrape in southern portion	230	Cherry Creek RNA	79-80
*10. Douglas-fir/oceanspray/salal community	229	None	73-75, 79
*11. Douglas-fir, 25-50 years old (old burn)	229	None	85-87
*12. Douglas-fir/salal community, 100-150 years old	229	None	79-80
*13. Douglas-fir/swordfern community, 100-150 years old	229	None	79-80
*14. Upland red alder stand with two perennial streams	221	None	61-63 85-87
Pacific Silver Fir Zone:			
*15. Old-growth noble fir forest		None	98
*16. Old-growth Pacific silver fir-western hemlock forest		None	98
Special types:			
*17. Coastal dune mosaic with a variety of dune types, tree islands, deflation plains, and early successional stages		None	291-295
*18. Parabola dune complex and surroundings		None	291-294
19. Coastal headland herbaceous communities		Cascade Head Nature Conservancy Area	291-292 297
*20. Grass bald on Coast Range mountain		None	90-91
*21. "Rock garden" community on Coast Range mountain		None	90-91
*22. Riparian hardwoods		None	61-63
*23. Coastal headlands shrub community		None	

*Cells presently lacking adequate representation.

Table 42.--*Aquatic cells in the Oregon Coast Ranges Province*

Cell[1]	Present representation	Remarks
* 1. Major stream drainage in Sitka spruce-western hemlock with anadromous fish	None	Stream should drain directly to the ocean
* 2. Major stream drainage in Douglas-fir, with anadromous fish	Would be filled by establishment of proposed Flynn Creek RNA	Should be inland from the coast
* 3. Two side-by-side perennial streams draining alder-dominated forest	None	
* 4. Low-gradient coastal stream with a sandy bottom, with good riparian mammal habitat	None	Should be south of Florence
* 5. Typical headwaters section of a high-elevation stream, with noble fir or Pacific silver fir forest	None	
* 6. Freshwater lake in sand dunes	None	
* 7. Low-elevation eutrophic lake	None	
* 8. Permanent ponds in sand dunes	None	
* 9. Vernal ponds in sand dunes	None	
*10. Typical Sitka spruce swamp	None	
*11. Typical skunk cabbage marsh	None	
*12. Willow-sedge marsh area	None	
*13. Coastal bog	Need would be filled with establishment of proposed Hunter Creek Bog RNA	

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 43.--*Rare and endangered vertebrate animal cells in the Oregon Coast Ranges*

Cell	Verified representation	Reference
Birds:		
*1. Northern spotted owl	Cherry Creek RNA, need an additional area	Gabrielson and Jewett 1940
Mammals:		
*2. Botta pocket gopher (2 subspecies involved)	None	Bailey 1936 Olterman and Verts 1972
3. White-footed vole	Neskowin Crest RNA	Bailey 1936 Johnson 1973 Maser 1966 Maser and Johnson 1967 Maser and Storm 1970 Olterman and Verts 1972
*4. Red tree vole (2 subspecies involved)	Coquille River Falls RNA, need an additional area	Bailey 1936 Johnson 1973 Maser 1966 Maser and Johnson 1967 Maser and Storm 1970 Olterman and Verts 1972

*Cells presently lacking adequate representation.

Table 44.--*Vascular plants of special interest in the Oregon Coast Ranges Province*

Species[1]	Distribution
Anemone oregana var. *felix*	Sphagnum bogs along immediate coast, Lincoln County
Arenaria paludicola[2]	Swamps along coast
Cardamine pattersonii[2]	Open slopes, Saddle and Sugarloaf Mountains and Onion Peak, Clatsop County
Cladothamnus pyrolaeflorus	Saddle Mountain and Onion Peak, Clatsop County; Blue Lake Lookout, Tillamook County
Cordylanthus maritimus[2]	Salt Marsh, Coos Bay
Douglasia laevigata var. *ciliolata*[2]	Saddle Mountain, Clatsop County
Empetrum nigrum	Open bluffs along coast, Lincoln and Curry Counties
Erigeron peregrinus var. *peregrinus*	Saddle Mountain and Onion Peak, Clatsop County
Erythronium revolutum[2]	Saddle Mountain, Clatsop County and along north coast
Filipendula occidentalis[2]	Along rivers (Trask, Wilson, and Tillamook), Clatsop to Lincoln Counties
Geum triflorum var. *campanulatum*	Saddle Mountain and Onion Peak, Clatsop County
Lasthenia minor ssp. *maritima*[2]	Rocky headlands, Lincoln County
Ledum groenlandicum	Bogs along coast, Clatsop and Tillamook Counties
Lewisia columbiana var. *rupicola*[2]	Saddle Mountain and Onion Peak, Clatsop County
Plantago macrocarpa	Cold, wet habitats near coast, Lincoln County
Ranunculus lobbii	Vernal pools along coast
Rhinanthus crista-galli	Saddle Mountain, Clatsop County, and Tillamook prairie
Romanzoffia tracyi	Wet sea cliffs, Tillamook and Lincoln Counties
Salix hookeriana	Clatsop County
Saxifraga bronchialis var. *vespertina*	Saddle and Sugarloaf Mountains and Onion Peak, Clatsop County
Saxifraga caespitosa var. *emarginata*	Onion Peak, Clatsop County
Saxifraga occidentalis var. *latipetiolata*[2]	Saddle and Sugarloaf Mountains and Onion Peak, Clatsop County
Scoliopus hallii	Damp woods along streams, Tillamook County south
Senecio flettii	Onion Peak, Clatsop County
Sidalcea hendersonii	Sandy tidelands, mouth of Columbia River
Sidalcea hirtipes	Coastal mountains to bluffs along the ocean, Saddle Mountain, Clatsop County, to north Lincoln County
Silene douglasii var. *oraria*[2]	Bluff above sea, Tillamook Head
Sisyrinchium californicum	Wet ground along immediate coast, Lincoln and Lane Counties
Stellaria humifusa	Beaches and salt marshes, Lincoln County north
Synthyris schizantha[2]	Saddle Mountain and Onion Peak, Clatsop County
Vaccinium oxycoccos var. *intermedium*	Sphagnum bogs, Lincoln County north

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or their identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]The species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 45.--*Established Research Natural Areas in the Oregon Coast Ranges Province*

Name	Principal features	Agency[1]	Area Ha	Area Acres
Cascade Head Preserve	Oregon coastal headland with extensive grassland and conifer and red alder forest	TNC	121	300
Cherry Creek RNA	Coast Ranges Douglas-fir forest	BLM	239	590
Neskowin Crest RNA	Sitka spruce-western hemlock forests	FS	278	686

[1]BLM = Bureau of Land Management, FS = Forest Service, TNC = The Nature Conservancy.

Table 46.--*Additional Research Natural Areas needed in the Oregon Coast Ranges Province*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic natural areas:						
1. Stream drainage with anadromous fish and a small estuary in the Sitka spruce-Douglas-fir forest type	T-3,22,1,2 A-1 R&E-1,3,4	Reneke Creek, Cummins Creek area, Neptune State Park area	High	FS State	58-63	0204
2. Major stream drainage with anadromous fish in the Douglas-fir-western hemlock type	T-13,12,14,24 A-2 R&E-1,3,4	Flynn Creek	High	FS	79-80	0204
3. Red alder area drained by two perennial streams (for purposes of studying nutrient cycling)	T-14 A-3 R&E-3	Could be in either Sitka spruce or western hemlock zones	Low	BLM FS	61-63 85-87	0204 0205 0206
4. Coastal dune mosaic (including tree islands, deflation plains, and most major dune types), with freshwater lake and ponds	T-17 A-6,8,9	Umpqua Dunes Scenic Area (Oregon Dunes National Recreation Area)	High	FS	291-295	0207
5. Ocean-front Sitka spruce/salal and lodgepole pine/salal with swampy swales	T-1,2 A-10	Could be partially filled in Cape Lookout State Park	Medium	State	59-60 291	0207
6. Old-growth Pacific silver fir-western hemlock forest with headwaters portion of a stream	T-16 A-5 R&E-1,3	Northern Coast Range area	Medium	State Private	98	0206
Predominantly terrestrial natural areas:						
7. Old-growth Douglas-fir-western hemlock/swordfern and western hemlock/swordfern	T-4,6 R&E-4	Should be in central to northern portion of Coast Ranges	High	BLM State	79-80	0204 0206
8. Old-growth Douglas-fir-western hemlock/rhododendron/Oregongrape	T-8,10 R&E-4	In central to northern portion	High	BLM State	79-80	0204 0206

See footnotes at end of table.

Table 46.--*Additional Research Natural Areas needed in the Oregon Coast Ranges Province* (Continued)

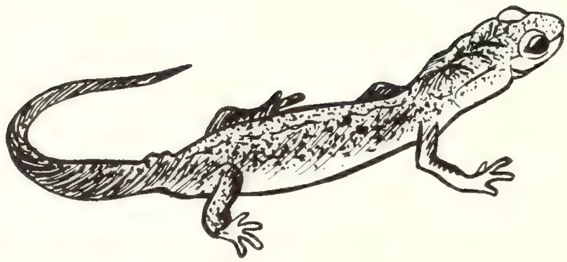
Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
9. Douglas-fir, 25-50 years old on old burn, and adjacent stand of noble fir	T-11,14	Should be natural regeneration; Tillamook Burn is possible area	Low	State	85-87	0206
10. Parabola dune complex	T-18	Sand Lake area	High	FS	291-294	0207
11. Grass bald and "rock garden" vegetation on a Coast Range peak	T-20,21	Onion Peak	Medium	State BLM	90-91	0206
Predominantly aquatic natural areas:						
12. Small lake and surrounding temperate forest	A-7	Eutrophic lake at low elevation	High	BLM Private		0205
13. Coastal bog	A-13 R&E-11,12	Clatsop County	High	State Private	68-69	0202 0207
14. Low gradient coastal stream (sandy bottom) with skunk cabbage marsh	A-4,11 R&E-3	Johnson Creek near Bandon or Tenmile Creek, Coos County	Medium	FS	68-69	020,
15. Willow-sedge marsh	A-12	Three-Mile Creek	High	FS	68-69	0207

[1]For a description of these cells see table 41 for terrestrial (T) ecosystems, table 42 for aquatic (A) ecosystems, and table 43 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate those cells which are considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential components.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of the type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. BLM = Bureau of Land Management, FS = Forest Service.

[4]See appendix V.



WESTERN OREGON INTERIOR VALLEYS PROVINCE

The Western Oregon Interior Valleys Province includes the valley bottoms and lowlands enclosed by the Cascade Range on the east and the Coast Ranges or Siskiyou Mountains on the west (fig. 1). The major units within the province are the Umpqua, Rogue, and Willamette River valleys. Of the three, the Willamette Valley is by far the largest; therefore it will receive major emphasis. Because of their location in the rain shadow of the Coast Ranges or the Siskiyou Mountains, the valleys are relatively warm, dry regions, especially in comparison with the remainder of western Oregon.

The topography of the Willamette Valley is characterized by broad alluvial flats separated by groups of low, generally basaltic hills. One of its most unusual features is its substantial width, which generally varies from about 30 to 50 km. The valley floor has a very gentle, north-facing slope and is, for the most part, underlain by thick, nonmarine sedimentary deposits of Pliocene-Pleistocene age. During at least two episodes of the Pleistocene, the entire valley was drowned by water and partially filled by silt to a depth of about 30 m. Recent alluvial deposits are limited in extent and confined to areas immediately adjacent to the Willamette River.

Soils on the Willamette Valley floor, derived from silty alluvial and lacustrine deposits, were formed under dominantly grassland vegetation. Well-drained soils situated on the Willamette River flood plain are deep, moderately dark colored, and range from sandy loam to silty clay loam in texture. Soils on terraces show more profile development, typically having silt loam surface horizons underlain by silty clay loam. Except for poorly drained soils in depressions, these are highly productive soils which are intensively used for agriculture.

The dominant valley bottom landforms in the Umpqua and Rogue River valleys are alluvial fans, terraces, and flood plains. In well-drained terrace locations, deep, dark-colored Prairie soils are common which are generally loam textured. However, black, clay-textured soils which undergo considerable expansion and contraction with wetting and drying are also common in the vicinity of Roseburg and Medford. Valley foothill soils are generally shallow and stony and, thus, extremely droughty during the dry summer period.

The natural ecosystems of the interior valleys are poorly known since these valleys were the first areas settled, with lands converted to agricultural and other uses. Nevertheless, many examples of natural or near-natural communities remain which indicate the valleys were mosaics of coniferous forests (especially on marginal hills), oak savannas and woodland, riparian or gallery forest, extensive and varied grasslands, and, in the southern valleys, chaparral-like shrub fields. Substantial variability in the characteristics of each of these ecosystem groupings is associated with a latitudinal change in climate; the progression is from the Willamette Valley, which is the coolest and wettest, south to the Rogue River valley, which is the warmest and driest. Additional variation in communities has been introduced by various disturbances such as fire, grazing, and logging. Aquatic ecosystems are varied and tend to be eutrophic in character even in their unpolluted state. Sloughs and slow-moving streams are associated with the major valley rivers, and marshes and ponds are common, particularly in the Willamette Valley.

Of terrestrial cells, 26 have been identified for the interior valleys of western Oregon (table 47). The basic strategy is to provide for representation of coniferous forest, oak woodlands, grasslands, and riparian hardwoods in each of the three major valley systems (Willamette, Umpqua, and Rogue Rivers). This should insure necessary diversity in these types for the natural area system.

Nine aquatic cells are listed for the interior valleys (table 48). Six of these are for valley-bottom ecosystems (ponds, oxbow lake, marshes, and slough segment) and the majority will probably be located within the Willamette Valley. Small valley-margin stream systems and a spring are also identified as necessary elements in a Research Natural Area system.

The areas selected to fill terrestrial and aquatic cells are expected to include the typical array of plant and animal species. Six vertebrate animals have been identified as rare and endangered cells requiring specific attention in selection and establishment of Research Natural Areas (table 49). Vascular plants of special interest include 19 from the Smithsonian list of threatened and endangered plants—a high proportion of the total list (table 50).

There are nine Federal Research Natural Areas and two reserves developed by The Nature Conservancy in the interior valleys of western Oregon (table 51). Since most of the areas are small they fill only 9 cells of a total of 41 identified cells in the province; 8 of the filled cells are terrestrial and 1 is aquatic.

Twenty-two additional Research Natural Areas should provide minimal representation of all identified terrestrial, aquatic, and rare and endangered cells (table 52). Because of the diverse nature of the cells and the relatively small size of potential sites for Research Natural Areas, most of these needed reserves have only one or two cells as essential elements.

Lead responsibilities in this heavily developed province rest primarily with State institutions, Bureau of Land Management, and private organizations (table 52). It is difficult to establish priorities in this province since the pace of urban and other developments is so rapid. As a generality, aquatic ecosystems and types suitable for agricultural development or logging need quickest attention.

Table 47.--*Terrestrial cells in Western Oregon Interior Valleys Province*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Conifer forests:			
1. Dry-site Douglas-fir forest on Willamette Valley foothills	229	Camas Swale and Fox Hollow RNA's	116-118
2. Douglas-fir-western hemlock forest on Willamette Valley foothills	230	Mohawk and Little Sink RNA's	116-118
3. Ponderosa pine-Douglas-fir forest in Willamette Valley margin location		Fox Hollow RNA	116-118
* 4. Western redcedar and associated conifers, northern Willamette Valley	227	None	116-118
* 5. Coniferous forest mixture, Umpqua Valley	Probably 229	None	118-119
* 6. Mixed coniferous forest (Douglas-fir probably dominant), Rogue Valley	243 or 244 or 229	None	118-119
* 7. Grand fir forest in the Willamette Valley		None	116-118
Oak woodland:			
* 8. Oregon white oak-grass savanna in the Willamette Valley	233	Token in Maple Knoll RNA and Cogswell-Foster Preserve, need additional area	111-114
* 9. Oregon white oak/snowberry forest in the Willamette Valley	233	None	111-114
10. Oregon white oak/poison oak forest in the Willamette Valley	233	Pigeon Butte and Maple Knoll RNA's	113
*11. Oak woodland in the Umpqua Valley	233	None	114-115
*12. Oregon white oak woodland in the Rogue Valley	233	None	114-115
*13. Oak-madrone woodland in the Rogue Valley	234	None	
*14. California black oak woodland in the Rogue Valley	246	None	114-115

See footnote at end of table.

Table 47.--*Terrestrial cells in Western Oregon Interior Valleys Province* (Continued)

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Grasslands:			
*15. Steep slope, xeric, valley margin prairie with rock outcrops in the Willamette Valley		None	119-123
*16. Gentle slope or valley bottom mesic prairie in the Willamette Valley		None	119-123
17. Wet, poorly drained valley bottom prairie in the Willamette Valley		Willamette Floodplain RNA	119-123
*18. Typical grassland in the Umpqua Valley		None	119-123
*19. Typical grassland in the Rogue Valley		None	119-123
Riparian and other hardwood communities:			
20. Riparian black cottonwood/willow along the Columbia River		Tenasillahe Island RNA	124-126
*21. Riparian black cottonwood/willow along the Willamette River		None	124-126
*22. Oregon ash in the Willamette Valley		Token in Willamette Floodplain RNA, need additional area	124-126
23. Riparian woodland in the Umpqua Valley		Myrtle Island RNA	124-127
*24. Riparian woodland in the Rogue Valley		None	124-127
25. Bigleaf maple forest		Maple Knoll and Little Sink RNA's	
Shrub communities:			
*26. Chaparral (*Ceanothus-Arctostaphylos*) in the Rogue Valley		None	124

*Cells presently lacking adequate representation.

Table 48.--*Aquatic cells in Western Oregon Interior Valleys Province*

Cell[1]	Present representation	Remarks
*1. Oxbow lake in the Willamette Valley	None	
*2. Eutrophic permanent pond	Little Sink RNA	Only token representation in RNA, need additional area
*3. Typical vernal pond	None	
*4. Small stream drainage along the east side of the Willamette Valley	None	
*5. Small stream drainage along the west side of the Willamette Valley	None	
6. Typical slough along large stream in the Willamette Valley	Willamette Floodplain RNA	
*7. Mineral spring in valley fringe area	None	
*8. Valley bottom marsh in the Willamette Valley	None	
*9. Valley bottom marsh in the Umpqua or Rogue River Valley	None	

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 49.--*Rare and endangered vertebrate animal cells in the Western Oregon Interior Valleys Province*

Cell	Verified representation	Reference
Amphibians:		
*1. Marys Peak salamander	None	
Reptiles:		
*2. Sharp-tailed snake	None	Stebbins 1954 Storm 1966
*3. California mountain kingsnake	None	Stebbins 1954
*4. Common kingsnake	None	Stebbins 1954
*5. Western rattlesnake	None	Stebbins 1954 Storm 1966
Mammals:		
*6. White-footed vole	None	Bailey 1936 Maser and Storm 1970 Olterman and Verts 1972 Johnson 1973 Maser 1966 Maser and Johnson 1967

*Cells presently lacking adequate representation.

Table 50.--*Vascular plants of special interest in the Western Oregon Interior Valleys Province*

Species[1]	Distribution
Allium unifolium	Near Willamina, Yamhill County
Androsace acuta	Rogue River Valley
Aster chilensis ssp. *hallii*[2]	Grasslands, Willamette Valley
Aster curtus	Grasslands, northern Willamette Valley
Aster vialis[2]	Oak woodlands, Lane and Douglas Counties
Brodiaea venusta	Garden Valley, Douglas County
Camassia leichtlinii var. *leichtlinii*	Moist fields and along highway near Roseburg, Douglas County
Cardamine penduliflora[2]	Lowland ponds and marshes, Willamette Valley east of Coast Ranges
Castilleja levisecta	Swamps, northern Willamette Valley
Delphinium leucophaeum[2]	Fields, northern Willamette Valley; now largely restricted to ditches and fence rows
Delphinium nuttallii	Gravelly outwash "prairies" and basaltic cliffs, Clackamas County
Delphinium pavonaceum[2]	Fields in Benton, Polk, and Clackamas Counties; mainly along fence rows
Erigeron decumbens	Grassland, Willamette Valley
Eryngium petiolatum[2]	Open ground, especially in spring-wet and summer-dry habitats, Willamette Valley and along Columbia River to the Gorge
Euonymus occidentalis	Near Portland, Clackamas County (Tryon Creek State Park)
Howellia aquatilis	In ponds on Sauvies Island, Columbia County, and near Salem, Marion County
Iris tenax var. *gormanii*	Along Scoggins Creek, Washington County, and Dairy Creek, Columbia County
Lathyrus holochlorus[2]	Fence rows and partially cleared land, Willamette Valley
Limnanthes floccosa ssp. *grandiflora*[2]	Near White City, Jackson County
Limnanthes floccosa ssp. *pumila*[2]	Vernal rocky flats, Table Rock, Jackson County
Limnanthes gracilis[2]	Seepage slopes, Rogue River Valley
Lomatium bradshawii[2]	Willamette Valley from Salem to Eugene; present in Willamette Floodplain RNA
Lotus pinnatus	Streambanks and meadows in valleys west of Cascade Mountains
Microcala quadrangularis	Moist prairies, Willamette and Umpqua Valleys
Microseris acuminata	Grassy flats, Sam's Valley, Jackson County
Microseris laciniata ssp. *leptosepala*	Grasslands, northern Willamette Valley

See footnotes at end of table.

Table 50.--*Vascular plants of special interest in the Western Oregon Interior Valleys Province* (Continued)

Species[1]	Distribution
Mimulus tricolor	Vernal pools, central Willamette Valley
Pellaea andromedaefolia	Dry stony areas, Douglas County
Perideridia erythrorhiza[2]	Grasslands, Umpqua Valley to Grants Pass
Phacelia verna[2]	Basalt cliffs, Umpqua Valley
Plagiobothrys hirtus[2]	Boggy ground near Drain, Umpqua Valley
Plagiobothrys hirtus var. *corallicarpus*[2]	Grasslands, Rogue River Valley near Grants Pass
Plagiobothrys lamprocarpus[2]	Grants Pass, Josephine County
Poa laxiflora	Multnomah, Clackamas, and Benton Counties
Pogogyne ziziphoroides	Agate desert, Jackson County
Ranunculus austro-oreganus	Dry ground near Medford, Jackson County
Sagittaria latifolia	In shallow water along streams and in swamps, northern Willamette Valley
Sedum stenopetalum ssp. *ciliosum*	Dry cliffs, Umpqua Valley near Roseburg, Douglas County
Sidalcea campestris[2]	In pastures and along roadsides, Willamette Valley; present in Willamette Floodplain RNA
Sidalcea cusickii[2]	Open fields and roadsides, Coquille and Umpqua River Valleys
Sidalcea nelsoniana[2]	Moist open ground, Willamette Valley between Portland and Salem; present in Willamette Floodplain RNA
Silene hookeri ssp. *pulverulenta*	Grasslands, Josephine and Jackson Counties
Trillium chloropetalum	Streambanks to damp woods, Willamette Valley
Viola douglasii	Open grasslands, Jackson County
Viola hallii	Grasslands, Douglas and Josephine Counties
Viola howellii	Moist woods and farmlands, Willamette Valley

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]Species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 51.--*Established Research Natural Areas in Western Oregon Interior Valleys Province*

Name	Principal features	Agency[1]	Area	
			Ha	Acres
Camassia Natural Area	Oak, madrone, camas, and aspen associated with openings, floristically rich	LCC TNC	9	23
Camas Swale RNA	Dry Douglas-fir forest in foothills of Willamette Valley	BLM	130	320
Cogswell-Foster Preserve	Oregon white oak and Oregon ash woodlands and seminatural grasslands in central Willamette Valley	TNC	34	83
Fox Hollow RNA	Dry Douglas-fir and ponderosa pine forest in foothills of the Willamette Valley	BLM	51	125
Little Sink RNA	Slump ponds and conifer-bigleaf maple forest on margin of the Willamette Valley	BLM	32	80
Maple Knoll RNA	Bigleaf maple stands on knoll in Willamette Valley	FWS	40	100
Mohawk RNA	Douglas-fir, western hemlock, and western redcedar forest in foothills of the Willamette Valley	BLM	61	150
Myrtle Island RNA	California laurel stands on an island in the Umpqua River	BLM	11	28
Pigeon Butte RNA	Oregon white oak stands on a knoll in the Willamette Valley	FWS	28	70
Tenasillahe Island RNA	Black cottonwood-willow stand on island in lower Columbia River	FWS	75	185
Willamette Floodplain RNA	Willamette Valley bottomland grass and Oregon ash communities	FWS	97	239

[1]BLM = Bureau of Land Management, FWS = Fish and Wildlife Service, LCC = Lewis and Clark College, TNC = The Nature Conservancy.

Table 52.--*Additional Research Natural Areas needed in the Western Oregon Interior Valleys Province*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic natural area:						
1. Oregon ash forest with eutrophic permanent pond and vernal pond	T-22 A-2,3	Preferably in southern Willamette Valley	Medium	State Private	124-126	0501
Predominantly terrestrial natural areas:						
2. Western redcedar and associated conifers	T-4	In northern portion of the Willamette Valley	Medium	State Private	116-118	0502 0503
3. Oregon white oak savanna	T-8 R&E-2,3,4	Willamette Valley	High	State Private	111-114	0502
4. Oregon white oak/snowberry forest	T-9	Willamette Valley	High	State Private	111-114	0502
5. Grand fir forest in the Willamette Valley	T-7,8,9	MacDonald State Forest	Medium	State	116-118	0502
6. Riparian black cottonwood-willow forest	T-21	Along the Willamette River	Low	State	124-126	0501
7. Steep slope, xeric, valley-margin prairie, with talus areas and western rattlesnake	T-15 R&E-5	Willamette Valley	High	State Private	119-123	0503
8. Gentle slope or valley bottom mesic prairie	T-16	Willamette Valley	High	State Private	119-123	0502
9. Coniferous forest mixture in the Umpqua River valley	T-5		High	BLM	118-119	
10. Oak woodland-grassland mosaic in the Umpqua Valley	T-11,18 R&E-2,3,4		High	BLM Private	114-115 119-123	
11. Mixed coniferous forest in the Rogue River valley	T-6 R&E-3,4		High	BLM	118-119	0301
12. Oregon white oak and oak-madrone forest mixed with grassland, Rogue Valley	T-12,13,19 R&E-2,3,4		High	BLM Private	114-115 119-123	0301
13. California black oak in the Rogue River valley	T-14 R&E-2,3,4		Medium	BLM	114-115	0301

See footnotes at end of table.

Table 52.--*Additional Research Natural Areas needed in the Western Oregon Interior Valleys Province* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
14. Chaparral (*Ceanothus-Arctostaphylos*) in the Rogue Valley	T-26	Possibly with oak or ponderosa pine	Low	BLM	124	0301
15. Riparian woodland along a major stream in the Rogue Valley	T-24	To provide comparison with west-side riparian type	Medium	State BLM	124-127	0301
Predominantly aquatic natural areas:						
16. Oxbow lake in the Willamette Valley	A-1	,	Medium	Private State		0501
17. Small stream drainage on the east side of the Willamette Valley	A-4		High	Private State		0503
18. Small stream drainage on the west side of the Willamette Valley	A-5 R&E-1,6	East slope of Marys Peak-Summit area	High	Private State		0503
19. Mineral spring in valley fringe area frequented by band-tailed pigeons	A-7		High	Private BLM		
20. Valley bottom marsh in the Willamette Valley	A-8	McFadden Marsh in W. L. Finley National Wildlife Refuge	High	FWS State Private		0501
21. Valley bottom marsh in the Umpqua or Rogue Valley	A-9		High	BLM State Private		
Natural area for protection of rare or threatened species:						
22. Table Rock area north of Medford--for protection of rare plant species. Should include vernal ponds and stony flats		Located just north of Rogue River. Species to be protected include *Pilularia americana*, *Limnanthes floccosa*, and *Mimulus tricolor*	High	Private State County BLM		0301

[1]For a description of these cells see table 47 for terrestrial (T) ecosystems, table 48 for aquatic (A) ecosystems, and table 49 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate those cells which are considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential components.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of the type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. BLM = Bureau of Land Management, FWS = Fish and Wildlife Service.

[4]See appendix V.

SKIYOU MOUNTAINS PROVINCE, OUTHWESTERN OREGON

The Siskiyou Mountains Province (fig. 1) is largely a region of extremely rugged, deeply dissected terrain. Mountain crests, comprised of steeply folded and faulted pre-Tertiary strata, range in elevation from 600 m near the coast to approximately 1200 m in the east. Ridge accordance suggests an ancient and now greatly dissected peneplain. Many peaks rise above this summit peneplain, the highest of which is Mount Ashland.

Most of the rock types in the Siskiyou Mountains are extremely old and have undergone at least some metamorphism. Sedimentary and volcanic rocks, dating from the Paleozoic to the Jurassic, have been altered to a variety of metamorphic rock types, including schists, gneisses, marbles, and other metavolcanic or metasedimentary rocks. Large-scale intrusions of ultramafic rocks, which subsequently have been largely altered to serpentine, occurred during late Jurassic to early Cretaceous times. At approximately the same time, a variety of granitic rocks were intruded in the vicinity of Grants Pass and Ashland. These granitics and, to a larger extent, serpentine parent materials are extremely important in influencing plant distribution within the Siskiyou Mountains.

Soils fall into two main groupings—those in the western portion and those in the east. Soils in the eastern half generally reflect the effects of drier conditions, especially during the summer, whereas soils to the west tend to remain moist for longer periods of the year. Upland soils in the western portion are, for the most part, deep and well developed; typically they have a silty clay loam A horizon and a silty clay B horizon. Soils derived from serpentine are invariably unproductive, having very shallow and stony profiles. As a result of the drier conditions, soils in the eastern portion of the province tend to be less well developed and contain larger amounts of gravels and cobbles, and bedrock is generally within 1 m of the surface.

The ecosystems and biota are extremely diverse (Franklin and Dyrness 1973), the most diverse of any of the provinces in the two States. Environmental complexity—bedrock geology, climatic gradients from the ocean across the range to the eastern slopes, physiography—added to a history of frequent, severe fires produces a bewildering array of ecosystems. Contributing to complexity is a very large array of plant and animal species which are a mixture of endemic types with Californian and northwestern species at their northern and southern limits, respectively.

Forest ecosystems predominate, with conifers dominant along the coast (Douglas-fir, western hemlock, Port-Orford-cedar, and redwood), at higher elevations (white and Shasta red firs and Brewer spruce), and in some inland areas (ponderosa and sugar pines and Douglas-fir). The "mixed evergreen" forests of Douglas-fir with tanoak, Pacific madrone, and other evergreen hardwoods form perhaps the most distinctive body of forested ecosystems. Serpentine areas have open forests or savanna communities of Jeffrey pine and other tree species. Other ecosystems include forests, shrub fields, and herb lands on the ocean front, chaparral, pygmy pine forests, knobcone pine stands, and mountain balds.

Streams and rivers are the most characteristic aquatic ecosystems, although small lakes, ponds, vernal pools, and bogs occur over a wide range of elevations and on both serpentine and normal rock types.

The 26 identified terrestrial cells (table 53) are minimal; they allow for very little representation of variants of the more widespread ecosystems. The majority (14) identify what might be termed the typical, closed forest communities. Four cells are for ecosystems on serpentine, two for ocean-front types, and the remaining six identify a variety of special types from chaparral to ash-alder swamps.

The 14 identified aquatic cells (table 54) include stream systems associated with coniferous and mixed evergreen forests, lakes, ponds, and vernal pools at low and high elevations, and a coastal bog. Aquatic ecosystems in serpentine areas differ significantly in structure, composition, and function from those occurring on more chemically balanced geologic formations. Consequently, three cells are identified for a lake, stream system, and bog on serpentine bedrock.

It is assumed that the characteristic array of plant and animal species will be associated with these terrestrial and aquatic ecosystems. Eight vertebrate animals are identified as cells because of their rare or endangered status (table 55); several of these are endemic. There are many vascular plants of special interest in the Siskiyou Mountain region (table 56). Many of these are endemic, typically on serpentine areas; and 36 of the listed plants are on the Smithsonian list of threatened and endangered plants. This province is by far the richest in plants of special interest as well as having the largest number from the Smithsonian list.

There are five Federal Research Natural Areas in the Siskiyou Mountains Province (table 57) with three of these along the coastal margin of the mountains. These existing areas fill 11 of the 48 identified cells; 7 of these filled cells are terrestrial, 2 are aquatic, and 2 are rare and endangered animal cells. Aside from Research Natural Areas, the Kalmiopsis Wilderness and several botanical (such as Big Craggies) and other special areas provide protection for many of the plants of special interest.

Addition of 24 Research Natural Areas should provide for minimal representation of all of the terrestrial, aquatic, and animal cells identified in the province (table 58); this number should also provide for representative populations of many of the plants of special interest. Of the needed Research Natural Areas, five combine major terrestrial and aquatic cells; and the three which involve major stream drainages are of particular consequence. Ten of the Research Natural Area needs are mainly for terrestrial ecosystems, including two focused on unusual tree species—Baker cypress and Brewer spruce. Six needs relate to aquatic cells. The only Research Natural Area need in the two States exclusively aimed at rare and endangered vertebrates is a moist talus area in the Applegate River valley for two species of salamanders (No. 22). Finally, two areas are identified to protect concentrations of special interest vascular plants.

Completing a series of Research Natural Areas in this diverse province will be a large job. Identifying and establishing the three large stream drainages needed as Research Natural Areas is a particularly challenging part of the job although candidate areas are known for each. The heaviest lead responsibility lies with the Forest Service, although the Bureau of Land Management and Oregon State agencies (along the coast) must also play major roles.

Priorities are greatest for terrestrial ecosystems representing major timber resources, almost all of the aquatic ecosystems (since these are subject to increasing disturbance), and areas outside the Kalmiopsis Wilderness which contain concentrations of rare and endangered species.

Table 53.--*Terrestrial cells in the Siskiyou Mountains Province, southwestern Oregon*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Sitka Spruce Zone:			
* 1. Ocean-front coniferous forest (probably Sitka spruce and western hemlock)		None	58-61
2. Redwood forest near the northern limits of its range	232	Wheeler Creek RNA	67-68
Western Hemlock Zone:			
3. Port-Orford-cedar-Douglas-fir on normal soils	231	Port Orford Cedar and Coquille River Falls RNA's	92-93
4. Douglas-fir-western hemlock forest	230	Port Orford Cedar RNA	72-80
Mixed-Conifer Zone:			
5. Pacific ponderosa pine with Douglas-fir in the eastern Siskiyous	244 245	Ashland RNA	138-139
* 6. Pacific ponderosa pine with Douglas-fir in the western Siskiyous	244 245	None	138-139
7. Mixed-conifer forest with sugar pine, Douglas-fir, and ponderosa pine	243	Ashland RNA	138-139
Mixed-Evergreen Zone:			
* 8. Mixed-evergreen forest (Douglas-fir and evergreen hardwoods)	234	None	133-136
* 9. Tanoak-madrone forest	234	None	134-135
*10. Canyon live oak	249	None	134-136
*11. Knobcone pine	248	None	134-135

See footnote at end of table.

Table 53.--*Terrestrial cells in the Siskiyou Mountains Province, southwestern Oregon* (Continued)

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
White Fir and Shasta Red Fir Zone:			
*12. Shasta red fir-white fir forest	207	None	150-155
13. Brewer spruce on a poor site		Brewer Spruce RNA	
*14. Brewer spruce showing maximum development		None	
Special types:			
*15. Jeffrey pine-grass on serpentine soils at low elevation	247	None	306-307
*16. Jeffrey pine-grass on serpentine soils at high elevation	247	None	306-307
*17. Port-Orford-cedar-Douglas-fir on serpentine soils	231	None	306-307
*18. Serpentine vegetation matrix and normal soil island with good representation of contacts		None	306-307
*19. Ocean-front shrub lands		None	298-300
*20. Ocean-front herb lands		None	298-300
*21. Typical chaparral communities		None	136
*22. Pygmy lodgepole pine forest on Blacklock soil		None	
*23. Riparian hardwood forest along a major west-side river (with alder, bigleaf maple, and myrtle)		None	
*24. Baker cypress in the eastern Siskiyous		None	
25. Ash-alder swamp		Port Orford Cedar RNA	
*26. Mountain herb lands at high elevations (grassland balds)		None	136

*Cells presently lacking adequate representation.

Table 54.--*Aquatic cells in Siskiyou Mountains Province, southwestern Oregon*

Cell[1]	Present representation	Remarks
* 1. Major stream drainage in coniferous forest	None	
* 2. Major stream drainage in mixed-evergreen forest	None	
* 3. Typical low-elevation lake	None	
* 4. Typical subalpine lake	None	
* 5. Lake in serpentine area at mid- to high-elevations	None	
6. Permanent pond at low elevation in mixed coniferous forest	Port Orford Cedar RNA	
7. Permanent pond at mid- to high-elevation in subalpine forest	Brewer Spruce RNA	Rabbit Lake
* 8. Typical vernal pond at low elevation	None	
* 9. Typical vernal pond at mid- to high-elevation	None	
*10. Stream drainage in serpentine at mid- to high-elevation	None	
*11. Cave and large cold springs	None	
*12. Typical marsh area	None	
*13. Typical coastal bog	None	
*14. Mountain bog in serpentine area	None	With *Darlingtonia*

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 55.--*Rare and endangered vertebrate animal cells in the Siskiyou Mountains Province, southwestern Oregon*

Cell	Verified representation	Reference
Amphibians:		
1. Del Norte salamander	Wheeler Creek and Port Orford Cedar RNA's	Stebbins 1954
*2. Siskiyou Mountain salamander	None	Stebbins 1954 Storm 1966
3. California slender salamander	Wheeler Creek RNA	Stebbins 1954
*4. Black salamander	Verified minimal representation in Ashland RNA, need additional area	Stebbins 1954 Storm 1966
Mammals:		
*5. Ashland shrew	None--probably in Ashland RNA	Bailey 1936 Olterman and Verts 1972
*6. Pinon mouse (subspecies *sequoiensis*)	None	Bailey 1936
*7. White-footed vole	None	Bailey 1936 Johnson 1973 Maser 1966 Maser and Johnson 1967 Maser and Storm 1970 Olterman and Verts 1972
*8. Red tree vole (subspecies *longicaudus*)	None	Bailey 1936 Johnson 1973 Maser 1966 Maser and Johnson 1967 Maser and Storm 1970 Olterman and Verts 1972

*Cells presently lacking adequate representation.

Table 56.--*Vascular plants of special interest in the Siskiyou Mountains Province, southwestern Oregon*

Species[1]	Distribution
antum jordanii	Rocky canyons, lower Rogue River
ium bolanderi	Stony flats, Douglas and Josephine Counties
ium falcifolium	Serpentine slopes, southern Josephine County
ium siskiyouense	Grassy slopes, Siskiyou Summit, Jackson County
ennaria suffrutescens[2]	Rocky hillsides, Illinois Valley, Josephine and Curry Counties
bis aculeolata[2]	On serpentine, Josephine and Curry Counties
bis koehleri var. *koehleri*	Rocky banks along Umpqua River near Roseburg, Douglas County
bis koehleri var. *stipitata*[2]	Rocky banks, Illinois Valley, Josephine County
bis modesta	Rocky banks, Rogue River Canyon near Galice, Josephine County
bis oregona[2]	Rocky hillsides, southern Jackson and Josephine Counties
tostaphylos cinerea	Brushlands, Illinois Valley, southern Josephine County
tostaphylos hispidula	Rocky summits, Josephine and Curry Counties
naria howellii	On serpentine, Josephine and Curry Counties
ica cernua	On serpentine, Illinois Valley, Josephine County
ica spathulata	Open woods, Curry and Josephine Counties
lenium septentrionale	Along North Umpqua River, Douglas County
er brickellioides[2]	Dry rocky slopes, Josephine and Curry Counties
er siskiyouensis	Forested slopes
ragalus accidens var. *hendersonii*	Open hillsides, Josephine County
ragalus umbraticus	Dry woods, Douglas and Josephine Counties
samorhiza platylepis	On serpentine, central Josephine County
soniella oregana	Mountain bogs, southern Josephine and Curry Counties
diaea dissimulata	Dry hills, Josephine County
ochortus greenei[2]	Thickets, southern Jackson County
ochortus howellii	Dry slopes, Umpqua and Illinois Valleys
ochortus indecorus	Open slopes, Sexton Mountain, Josephine County
ochortus uniflorus	Wet meadows, Illinois Valley, Josephine County
nassia howellii	Meadows, Josephine and Jackson Counties
stilleja brevilobata[2]	Rocky slopes, Josephine County
stilleja elata	In bogs, usually on serpentine, southern Josephine County
rsium acanthodontum	Lower Rogue River Canyon to the coast, Curry County
rsium ciliolatum[2]	Dry hillsides near Ashland, Jackson County
rkia amoena var. *pacifica*	High ocean bluffs, Lincoln and Curry Counties
ntonia andrewsiana	Under redwoods, southern Curry County
dylanthus viscidus	On serpentine, Josephine and Jackson Counties

See footnotes at end of table.

Table 56.--*Vascular plants of special interest in the Siskiyou Mountains Province, southwestern Oregon* (Continued)

Species[1]	Distribution
Cupressus bakeri	Open woods, northern Jackson and southern Josephine Counties
Cypripedium calceolus var. *parviflorum*	Mount Peavine, Josephine County
Cypripedium californicum[2]	Bogs and springs, Josephine and Curry Counties
Cypripedium fasciculatum	Coniferous forests, Josephine and Jackson Counties
Darlingtonia californica[2]	Sphagnum bogs, Josephine and Curry Counties (and along coast)
Dentaria gemmata	Streamsides, Josephine County
Dicentra formosa ssp. *oregana*[2]	Southwestern Josephine and Curry Counties
Dicentra pauciflora	High altitudes
Draba howellii	High rocky summits
Empetrum nigrum	Open coastal bluffs, Lincoln and Curry Counties
Epilobium rigidum	Dry rocky washes, Curry and Josephine Counties
Erigeron bloomeri var. *nudatus*[2]	On serpentine, Josephine and Curry Counties
Erigeron cervinus	Meadows and canyon banks, Curry to Jackson Counties
Erigeron delicatus[2]	Along streams, central Curry County
Erigeron petrophilus	Dry cliffs, Curry to Jackson Counties
Eriogonella membranacea	Dry slopes, Jackson County
Eriogonum incanum	Summit of Mount Ashland, Jackson County
Eriogonum pendulum	Dry stony ground, southern Josephine County
Eriogonum ternatum	Gravelly flats, southern Josephine County
Erythronium citrinum	Open woods, southern Josephine County
Erythronium howellii[2]	Open woods along Illinois River, southern Josephine County
Fritillaria gentneri	Oak woodlands in foothills, Jackson and Josephine Counties
Fritillaria glauca	On serpentine, Josephine and Curry Counties
Fritillaria recurva	Open woods in foothills
Gentiana bisetaea[2]	Seepage slopes, Josephine and Curry Counties
Haplopappus racemosus ssp. *congestus*[2]	On serpentine, Josephine County
Hieracium bolanderi	Mountains of Curry, Josephine, and Jackson Counties
Horkelia congesta ssp. *nemorosa*	Douglas, Josephine, and Jackson Counties
Horkelia hendersonii	Rocky summit of Mount Ashland, Jackson County
Horkelia sericata	On serpentine, Josephine, Jackson, and Curry Counties
Hydrocotyle verticillata	Garrison Lake, Curry County
Iris bracteata	Pine forest, southern Josephine and Curry Counties
Iris innominata	Wooded banks, Illinois River drainage, present in Port Orford Cedar RNA
Juniperus communis var. *jackii*	On serpentine
Kalmiopsis leachiana	Dry mountain slopes, Curry County, Kalmiopsis Wilderness Area

See footnotes at end of table.

Table 56.--*Vascular plants of special interest in the Siskiyou Mountains Province, southwestern Oregon* (Continued)

Species[1]	Distribution
Lasthenia macrantha ssp. *prisca*[2]	Bluffs north of Gold Beach, Curry County
Lathyrus delnorticus	Along streams, Josephine and Curry Counties
Leucothoe davisiae	Hillside bogs, Curry County
Lewisia cotyledon[2]	Jackson, Josephine, and Curry Counties
Lewisia oppositifolia[2]	Moist serpentine slopes, Josephine and Curry Counties
Lilium bolanderi	Open hillsides, southern Josephine and Curry Counties
Lilium kelloggii	Open woods, southern Josephine County
Lilium occidentale[2]	Sphagnum bogs, Curry County
Lilium pardalinum	Bogs and springs
Lilium parvum	Mountain bogs and springs, southern Josephine County
Lilium rubescens	Wooded slopes, southern Josephine and Jackson Counties
Lilium vollmeri[2]	Hillside bogs, Josephine and Jackson Counties
Lomatium howellii	Southern Jackson and Josephine Counties
Lomatium tracyi	On serpentine
Lupinus aridus var. *ashlandicus*	Stony slopes, Mount Ashland, Jackson County
Lupinus mucronulatus	On serpentine, Waldo area, Josephine County
Microseris bigelovii	Coastal bluffs, Cape Blanco, Curry County
Microseris howellii[2]	On serpentine, Josephine and Jackson Counties
Microseris laciniata ssp. *detlingii*[2]	Grasslands, Siskiyou Pass, Jackson County
Microseris nutans ssp. *siskiyouensis*	Open rocky area near Waldo, Josephine County
Mirabilis greenei	Southern Jackson County
Monardella purpurea	Dry ground, northern Curry to southern Josephine Counties
Navarretia heterandra	Vernal pools, Jackson County
Orthocarpus cuspidatus	Grasslands, southern Klamath and Jackson Counties
Oxalis oregana var. *smallii*	Rogue River canyon near Galice, Josephine County
Pedicularis howellii	Coniferous forest along summits, Josephine County
Pellaea brachyptera	Dry rocky slopes, mountains of Jackson and Josephine Counties
Penstemon newberryi ssp. *berryi*	Summit of Siskiyou Mountains near Oregon Caves, Josephine County
Penstemon parvulus	Summit of Mount Ashland, Jackson County
Phacelia argentea	On old coastal dunes, Curry County
Phacelia capitata[2]	On serpentine, along Coquille River, Coos County
Phacelia leonis	Southern Josephine County
Phacelia peckii[2]	Moist flats, southern Jackson County
Picea breweriana	Southern Josephine County
Pinus sabiniana	Along Rogue River, Josephine County
Polystichum californicum	Coastal forest, Curry County
Polystichum mohrioides	On serpentine, mountain slopes
Potentilla glandulosa ssp. *ashlandica*	Wet meadows, Mount Ashland, Jackson County
Potentilla glandulosa ssp. *globosa*	Mount Ashland, Jackson County
Quercus morehus	Northern Douglas and southern Josephine Counties

See footnotes at end of table.

Table 56.--*Vascular plants of special interest in the Siskiyou Mountains Province, southwestern Oregon* (Continued)

Species[1]	Distribution
Quercus sadleriana	Mountains in Douglas, Josephine, Curry, and Jackson Counties
Romanzoffia tracyi	Wet sea cliffs, Curry County
Rudbeckia californica var. *glauca*	Bogs, Douglas, Curry, and Josephine Counties
Sanicula peckiana	On serpentine, Josephine and Curry Counties
Sanicula tracyi	On serpentine, southern Josephine County
Saxifraga fragarioides	Mountain cliffs, Josephine and Jackson Counties
Saxifraga howellii	Upper Coquille to lower Umpqua River, and along the Rogue River, Josephine County
Schoenolirion bracteosum[2]	Mountain meadows, southern Jackson and Josephine Counties
Sedum glanduliferum	Rock outcrops along Rogue River, Josephine County
Sedum laxum ssp. *heckneri*[2]	Dry cliffs, Jackson County
Sedum laxum ssp. *laxum*	On serpentine, Josephine County
Sedum laxum ssp. *perplexum*	Coastal cliffs, Curry County
Sedum purdyi	Associated with Brewer spruce, southern Jackson County
Senecio hesperius[2]	Mountain bogs on serpentine, Josephine County
Sidalcea malvaeflora ssp. *elegans*[2]	On serpentine, southern Josephine County
Sidalcea malvaeflora ssp. *patula*	Grassy slopes along immediate coast, Curry County
Sidalcea setosa[2]	Josephine County
Sisyrinchium californicum	Unique population of pink form near Pilot Rock, Jackson County
Sophora leachiana[2]	Oak-madrone forest, Mount Peavine, Josephine County
Streptanthus howellii	On serpentine, mountains of Josephine and Curry Counties
Synthyris reniformis var. *cordata*	Mixed woodlands on serpentine, Josephine and Curry Counties
Tauschia glauca	Woods along Rogue and Umpqua Rivers, Josephine and Curry Counties
Tauschia howellii[2]	Dry slopes, southwestern Jackson County
Thlaspi montanum var. *siskiyouensis*[2]	On serpentine, Josephine County
Trifolium howellii	Moist slopes in woods, mountains of Josephine and Jackson Counties
Trillium rivale	Streambanks, Josephine and Curry Counties
Vaccinium coccinium[2]	Sandy slopes and ridges, mountains of Josephine County
Vancouveria chrysantha[2]	Illinois River Valley, Josephine and Curry Counties
Vancouveria planipetala	Dry woods, coastal Curry County
Viola lanceolata var. *occidentalis*[2]	Sphagnum bogs, southern Josephine County
Viola lobata var. *psychodes*	Coniferous forests, O'Brien area, Josephine County
Viola ocellata	Woodlands, Douglas and Curry Counties
Woodwardia fimbriata	Wet banks, southern Josephine County
Zauschneria latifolia	Along lower Rogue and Illinois Rivers, Curry and Josephine Counties

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]Species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 57.--*Established Research Natural Areas in the Siskiyou Mountains Province, southwestern Oregon*

Name	Principal features	Agency[1]	Area	
			Ha	Acres
Ashland RNA	"Pacific" ponderosa pine, pure and mixed with Douglas-fir, on granitic soils	FS	570	1,408
Brewer Spruce RNA	Brewer spruce with many other conifers	BLM	85	210
Coquille River Falls RNA	Port-Orford-cedar stands	FS	202	500
Port Orford Cedar RNA	Port-Orford-cedar and Douglas-fir stands	FS	454	1,122
Wheeler Creek RNA	Redwood-Douglas-fir forests near the northern limits of redwood	FS	135	334

[1]BLM = Bureau of Land Management, FS = Forest Service.

Table 58.--*Additional Research Natural Areas needed in the Siskiyou Mountains Province, southwestern Oregon*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic natural areas:						
1. Coniferous forest and major stream drainage (at low- to mid-elevations)	T-4,6,9 A-1 R&E-7,8	Anvil Creek (Powers District, Siskiyou National Forest)	High	FS BLM	79-80 136-143	0306
2. Mixed-evergreen forest (Douglas-fir-evergreen hardwoods) and major stream drainage	T-8,9,18 A-2	Proposed Store Gulch RNA or Dry Creek in Sixes River drainage	Medium	FS State	133-136	0302
3. Large mid- to high-elevation area with serpentine vegetation matrix and normal soil island or contact--should include typical serpentine Port-Orford-cedar--Douglas-fir, Jeffrey pine-grass, plus a small lake, and stream drainage	T-16,17,18 A-5,10	Baldface Creek drainage (Chetco District, Siskiyou National Forest). Will include many serpentine endemic plant species (table 56)	Low	FS	306-307	0302 0304
4. Coastal pigmy forest (lodgepole) and Blacklock soil with vernal pond	T-22 A-8	Blacklock Point area in Floras Lake State Park	High	State Private		0207
5. Shasta red fir-white fir forest with vernal pond	T-12 A-9	Applegate drainage	Low	BLM FS	150-155	0303
Predominantly terrestrial natural areas:						
6. Coastal coniferous forest (Douglas-fir-Sitka spruce-western hemlock)	T-1 R&E-7,8	Samuel Boardman State Park	Medium	State	58-61	0304
7. Pacific ponderosa pine with Douglas-fir in the western Siskiyous	T-6	Myers Flat (Galice District, Siskiyou National Forest)	High	FS	138-139	0305
8. Tanoak-madrone and knobcone pine forest	T-9,11 R&E-6	Chetco District, Siskiyou National Forest	Medium	FS	134-135	0304
9. Canyon live oak type	T-10 R&E-6		Low	FS	134-136	0304

See footnotes at end of table.

Table 58.--*Additional Research Natural Areas needed in the Siskiyou Mountains Province, southwestern Oregon* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
10. Coastal shrublands on ocean-facing slopes	T-19	South of Humbug Mountain State Park	Medium	State	298-300	0304
11. Coastal herb lands on ocean-facing slopes	T-20		Medium	State	298-300	0304
12. Large chaparral area also containing mountain herb lands (grass land balds)	T-21,26	Big Craggies Botanical Area	Low	FS	136	0304
13. Riparian hardwood forest along a major west-side stream	T-23	Containing alder, big leaf maple, myrtle	Low	FS BLM		0301
14. Baker cypress (*Cupressus bakeri*)	T-24 R&E-2,4	In eastern Siskiyous near California border	Low	BLM FS		0303
15. Brewer spruce showing maximum development on a good site	T-14	Sanger Lake	Low	FS		0304
Predominantly aquatic natural areas:						
16. Low-elevation lake	A-3		High	BLM FS		
17. Mid- to high-elevation lake (subalpine)	A-4		High	FS BLM		
18. Cave with large, cold springs	A-11	Near Oregon Caves	High	State Private		0303
19. Typical marsh area	A-12		High	State Private FS		
20. Mountain bog in serpentine area	A-14	Proposed Hunter Creek Bog RNA	High	BLM		0306
21. Coastal bog	A-13	Should include *Lilium occidentale*	High	BLM FS		0207

See footnotes at end of table.

Table 58.--*Additional Research Natural Areas needed in the Siskiyou Mountains Province, southwestern Oregon* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Natural area for protection of rare or endangered animal species:						
22. Moist talus areas in the Applegate River valley--habitats for Siskiyou Mountain salamander and black salamander	R&E-2,3	Areas to be selected	High			0303
Natural areas for protection of plant species of special interest[5]:						
23. Illinois River Valley including bog area--for protection of a large number of serpentine and serpentine bog plant species		Near Rough and Ready Creek. Species protected to include *Erythronium howellii*, *Lilium rubescens*, *Cypripedium montanum*, *Isopyrum hollii*, *Viola occidentalis*, *Gentiana bisetaea*, *Castilleja elata*, and *Microseris howellii*	High	FS		0303
24. Hobson Horn area--includes Sadler oak, Brewer spruce, and a variety of rare plants		Siskiyou National Forest, west of Galice. Species protected to include *Sophora leachiana*, *Tauschia glauca*, *Tauschia howellii*, and *Sarcodes sanguinea*	High	FS		0305

[1]For a description of these cells see table 53 for terrestrial (T) ecosystems, table 54 for aquatic (A) ecosystems, and table 55 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate those cells which are considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential components.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of the type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. BLM = Bureau of Land Management, FS = Forest Service.

[4]See appendix V.

[5]There are several outstanding sites with concentrations of special interest plants. Waldo, near O'Brien in Josephine County, has the largest group. "Hanging Bog" above Josephine Creek, Eight Dollar Mountain, and Limpy Creek are other major sites in Josephine County.

ESTERN SLOPES AND CREST PROVINCE, REGON CASCADES

The Cascades in Oregon include two distinct physiographic and geologic areas—the Western Cascades and the High Cascades (fig. 1). The High Cascades, on the east, include all major peaks of the range (e.g., Mount Hood, Mount Jefferson, Three Sisters) and originated during late Pliocene to Pleistocene times. The Western Cascades consist of older volcanic flows laid down during the Oligocene and Miocene.

The relief of the Western Cascades is generally rugged in the eastern portions, but slopes are more gentle to the west. Over much of the area there is a striking accordance of main ridge crests at an average elevation of about 1500 m. Some glaciation occurred in the Western Cascades during the Pleistocene, but glaciers were largely confined to the principal stream valleys and had little effect on shaping present day landforms. The topographic characteristics of the younger High Cascades are considerably different. The High Cascades area is essentially a gently rolling high plateau interrupted at intervals by deep glaciated stream channels and volcanic cones and peaks. Volcanic activity, which reached its maximum during the Pleistocene, has continued until recently; some flows of lava are only several hundred years old.

Basalt, andesite, and pyroclastics (tuffs and breccias) are the most common bedrock materials in the Western Cascades. Since pyroclastic parent materials are readily weatherable, soils from these materials tend to be deep and fine textured, especially on gentler slopes. Pyroclastic soils are frequently imperfectly drained, and mass soil movements (e.g., slumps and earthflows) are common. Soils derived from basalt and andesite in the Western Cascades are generally well drained and tend to be stonier and coarser textured. On steep slopes profiles are poorly developed with dark-brown gravelly loam or sandy loam surface horizons. At higher elevations these soils often contain noticeable amounts of aerially deposited volcanic ash and pumice.

The High Cascades is an area dominated by immature soils developed in volcanic ejecta and soils showing more profile development which are derived from glacially deposited materials. Soils on glacial till are most common in the northern section and are characteristically deep and well drained with stony or gravelly sandy loam or loam textures. In the central and southern portions of the High Cascades, extensive areas are mantled with deposits of volcanic ejecta, such

as pumice, cinders, and ash. Soils in these materials show little profile development beyond the formation of thin, dark-colored A horizons.

Dense coniferous forests are dominant ecosystems on the western slopes and crest of the Oregon Cascade Range (Franklin and Dyrness 1973). Major patterns of variability in composition and productivity of these forests are associated with elevation and with regional and local climatic gradients; the most notable of these gradients is the pattern of increasing temperature and decreasing precipitation moving from north to south along the range.

In the northern half of the province, forests of Douglas-fir, western hemlock, and western redcedar grade into communities characterized by Pacific silver and noble firs at higher elevations. Subalpine forests of mountain hemlock occur only on the highest ridges and peaks in the Western Cascades but are very extensively distributed along the entire crest of the High Cascades. In the southern half of the province (south of the Willamette-Umpqua River divide), montane forests are mixtures of Douglas-fir, sugar pine, incense-cedar, and white fir; Shasta red and white fir forests occupy the lower subalpine zone, below the mountain hemlock. A variety of meadow communities is associated with the higher ridges of the Western Cascades and subalpine parklands of the High Cascades; lava flows, pumice fields, riparian habitats, and rock cliffs and scree provide additional biotic diversity in the province.

Rivers and streams are the dominant aquatic ecosystems in the Western Cascades. Lakes and ponds, on the other hand, are common to abundant along the crest of the range in the High Cascades.

Twenty-seven terrestrial cells have been identified for the province (table 59). Eighteen cells provide for representation of the important forest ecosystems including variants of widespread or highly variable types. It is critical that the commercially important Douglas-fir and western hemlock forests in the Western Cascades be well represented, since these will be sites for research relevant to management of these forests. Nine cells identify montane and subalpine meadow and related subalpine and alpine ecosystems.

Identified aquatic cells total 17 (table 60). The majority provide for representation of streams, lakes, and ponds in contrasting habitats—for example, at low and high elevations and in southern and northern portions of the Cascade Range. Marshes, bogs, and hot springs round out the aquatic ecosystems needed.

Research Natural Areas established for the terrestrial and aquatic cells will presumably include the array of plant and animal species characteristic of these ecosystems. Seven rare or endangered vertebrate animal species have been identified which require specific consideration in selection and establishment of natural areas (table 61). Vascular plants of special interest include 21 from the Smithsonian list of endangered or threatened plants (table 62). The greatest concentration of these plants is in the Columbia River gorge, with the subalpine and alpine slopes of the major volcanic peaks (most notably Mount Hood and Crater Lake) as habitat for a second major group.

Six Research Natural Areas have already been established (table 63). These areas provide adequate coverage of 11 of the 51 identified cells—7 of the terrestrial, 3 of the aquatic and 1 rare and endangered animal. Existing Wilderness Areas, Crater Lake National Park, and other specially designated tracts already provide protection for a substantial number of the plant species.

Addition of 22 Research Natural Areas should provide for minimal representation of all identified terrestrial, aquatic, and animal cells (table 64). Five of these are for combined coverage of major terrestrial and aquatic cells.

Leadership in selection and establishment of the needed Research Natural Areas lies primarily with the Forest Service, but substantial contributions from the Bureau of Land Management, National Park Service, and Oregon State agencies are essential (table 64). Considerable progress has already been made in locating candidate areas, with at least 9 of the 22 needed areas identified or in process of establishment. Ecosystems which represent major timber types have high priority for action because of the rapid pace of logging and other activities (table 64). Low-elevation aquatic ecosystems also need early attention. Subalpine and alpine ecosystems, many of which are presently free from excessive pressure for development, have relatively low priority.

Table 59.--*Terrestrial cells in the Western Slopes and Crest Province, Oregon Cascades*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Western Hemlock Zone:			
* 1. Douglas-fir forest, 100-150 years old with range in understory from dry to moist communities (in Western Cascades and northern half of the State)	229	None (Search under way in Willamette National Forest)	72-88
2. Douglas-fir-western hemlock forest about 250 years old	229 230	Bagby RNA	72-88
* 3. Old-growth Douglas-fir-western hemlock forest with representative range in understory communities	230 229	Need will be filled with establishment of proposed Middle Santiam RNA	72-80
* 4. Typical low-site western hemlock stands occupying the summit of the High Cascades south of Mount Hood	224	None (Search under way in Mount Hood National Forest)	99
* 5. Old-growth western redcedar in the Western Cascades		None	81-82
Pacific Silver Fir Zone:			
6. Upper-slope mixed-conifer forest (Pacific silver fir-western hemlock, mountain hemlock-subalpine fir, etc.)	226	Bull Run, Olallie Ridge, and Wildcat Mountain RNA's	94-98
7. Typical noble fir forest	226	Wildcat Mountain and Bull Run RNA's	94-98
8. Mountain meadow-forest mosaic in the northern portion of the Western Cascades	227 or 228	Olallie Ridge RNA	152-153
Mountain Conifer Zone:			
9. Typical mountain hemlock forest in the Western Cascades	205	Wildcat Mountain RNA	103-106
*10. Typical mountain hemlock forest in the High Cascades	205	Need would be met by proposed area near Waldo Lake	103-106
11. Engelmann spruce-subalpine fir forest	206	Gold Lake Bog RNA	103-109
Mixed-Conifer Zone:			
12. Mixed-conifer forest at high elevations	243	Abbott Creek RNA	139-143
*13. Southwestern Oregon mixed-conifer forest at low elevations (Douglas-fir-incense-cedar-ponderosa pine with a variety of understory types)		None (Search under way in South Umpqua drainage, Umpqua National Forest)	138-145

See footnote at end of table.

Table 59.--*Terrestrial cells in the Western Slopes and Crest Province, Oregon Cascades* (Continued)

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
White Fir and Shasta Red Fir Zones:			
*14. Mature white fir-Douglas-fir forest in the High Cascades	211	None	150-152
*15. Typical Shasta red fir forest in the High Cascades covering a range of habitats	207	Establishment of proposed Wickiup Springs RNA would fill need	155-158
*16. Mountain meadow-forest mosaic in the southern portion of the Western Cascades		Establishment of proposed Cougar Butte RNA will fill need	152-153
Subalpine and alpine communities:			
*17. Whitebark pine in the High Cascades	208	None	272-275
*18. Subalpine meadow community mosaic in the High Cascades (with as many major communities represented as possible)		None	269-270
*19. Subalpine pumice and ash fields ("pumice deserts")		None	270
*20. Subalpine lava flow with representative vegetation		None	300-302
*21. Green fescue in the Mount Hood area		None	269-272
*22. Alpine needlegrass in the southern portion of the High Cascades		None	
*23. Alpine community mosaic		None	284-290
Special types:			
*24. Swale or swamp forest, Umpqua region (Oregon ash and ponderosa pine)		None	
*25. Moist temperate river terrace forest with Douglas-fir, western hemlock, western redcedar, and associated hardwoods	230	Some will be included in proposed Middle Santiam RNA	72-82
*26. Lodgepole pine at high elevations on pumice and ash soils	218	None	106-108
*27. Bigleaf and vine maple communities on talus slopes in the Columbia Gorge		None	91

*Cells presently lacking adequate representation.

Table 60.--*Aquatic cells in the Western Slopes and Crest Province, Oregon Cascades*

Cell[1]	Present representation
* 1. Low-elevation lake surrounded by Douglas-fir-western hemlock, in the northern portion of the province	None
* 2. Low-elevation lake surrounded by mixed-conifer forest in the southern portion of the province	None
* 3. Subalpine lake in the Western Cascades	None
* 4. Subalpine lake in the High Cascades	None
* 5. Typical alpine lake in the High Cascades	None
* 6. Low-elevation permanent pond, in the northern portion of the province	None
7. Subalpine permanent pond	Gold Lake Bog RNA
* 8. Alpine permanent pond	None
* 9. Low-elevation vernal pond, in the northern portion of the province	None
*10. Subalpine vernal pond	None
*11. Alpine vernal pond	None
*12. Low-elevation stream drainage in Douglas-fir-western hemlock, with anadromous fish	None
13. Low- to mid-elevation stream drainage in mixed-conifer forest	Abbott Creek RNA
*14. Subalpine stream drainage with Pacific silver fir-western hemlock forest	None
*15. Typical hot springs	None
*16. Bulrush-sedge marsh	None
17. Typical subalpine bog	Gold Lake Bog RNA

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation

Table 61.--*Rare and endangered vertebrate animal cells in the Western Slopes and Crest Province, Oregon Cascades*

Cell	Verified representation	Reference
Amphibians:		
*1. Larch Mountain salamander	None	Stebbins 1954 Storm 1966
*2. Oregon slender salamander	None	Stebbins 1954 Storm 1966
3. Spotted frog	Gold Lake Bog RNA	Stebbins 1954 Storm 1966
Birds:		
*4. Northern spotted owl	None	Gabrielson and Jewett 1940 Marshall 1969
Mammals:		
*5. Heather vole	None	Bailey 1936 Edwards 1955 Johnson 1973 Maser and Storm 1970 Olterman and Verts 1972 Shaw 1924
*6. White-footed vole	None	Bailey 1936 Johnson 1973 Maser 1966 Maser and Johnson 1967 Maser and Storm 1970 Olterman and Verts 1972
*7. Red tree vole (2 subspecies involved)	None	Bailey 1936 Johnson 1973 Maser 1966 Maser and Johnson 1967 Maser and Storm 1970 Olterman and Verts 1972

*Cells presently lacking adequate representation.

Table 62.--*Vascular plants of special interest in the Western Slopes and Crest Province, Oregon Cascades*

Species[1]	Distribution
Agoseris elata	Open woods, middle altitude, Cascade Range
Agrostis howellii[2]	Moist cliffs, south side of Columbia River Gorge
Allium schoenoprasum	Wet rocky ground, between low and high water along Columbia River gorge
Alnus sinuata	Unusual population on Angels Rest, Columbia River Gorge at low elevation
Anemone adamsiana	Along road from Tiller to Trail, Douglas and Jackson Counties
Arabis sparsiflora var. *atrorubens*	Open grassy slope, Columbia River Gorge, Klickitat County, Washington
Arabis suffrutescens var. *horizontalis*	Crater Lake National Park
Arenaria pumicola	Crater Lake and Mount McLoughlin, to Mount Jefferson
Arnica viscosa[2]	Near timberline, Crater Lake and Three Sisters
Asarum caudatum var. *viridiflorum*	Lake of the Woods, Klamath County
Aster gormanii[2]	Mount Jefferson to Breitenbush Lake, Marion County
Betula glandulosa var. *glandulosa*	Bogs at lower elevation, Cascade Mountains (Clackamas Lake, Clackamas County)
Bolandra oregona	Wet mossy rocks, both sides of Columbia River Gorge and along lower Willamette River
Botrychium pumicola	Crater Lake area and Paulina Mountains
Calamagrostis breweri	Alpine meadows, Mount Hood and Mount Jefferson
Calamagrostis howellii[2]	Cliffs of Columbia River Gorge, Multnomah and Hood River Counties, Oregon; Clark and Klickitat Counties, Washington
Carex macrochaeta	Multnomah Falls, Columbia River Gorge
Cimicifuga laciniata[2]	Wooded slopes, base of Mount Hood and in Columbia River Gorge
Collomia larsenii	Talus slopes on alpine peaks, Cascade Range
Collomia mazama[2]	Dry woods at high altitude, Mount McLoughlin and Crater Lake
Corallorhiza mertensiana (Yellow phase)	Coniferous forests, near Mount Hood and in Columbia River Gorge
Corydalis aquae-gelidae[2]	Very cold springs, upper Clackamas River drainage
Cypripedium montanum	Usually in open woods
Dicentra cucullaria	Moist woods, Columbia River Gorge, and along Sandy River tributary
Dodecatheon dentatum	Wet cliffs, Columbia River Gorge
Douglasia laevigata[2]	Cliffs and talus slopes, Columbia River Gorge

See footnotes at end of table.

Table 62.--*Vascular plants of special interest in the Western Slopes and Crest Province, Oregon Cascades* (Continued)

Species[1]	Distribution
Draba aureola	Alpine summits of volcanic peaks (Three Sisters)
Elmera racemosa	Rock crevices, alpine slopes; Mount Washington, Deschutes County, and Cow Horn Peak, Klamath County
Erigeron howellii[2]	Moist rocky places, south side of Columbia River Gorge
Erigeron oreganus[2]	Shady ledges, Columbia River Gorge, primarily on Oregon side
Eriogonum umbellatum var. *hausknechtii*	High mountain meadows
Erythronium klamathense	Woods, southwestern Klamath and southeastern Jackson Counties
Frasera umpquaensis[2]	Open woods and meadows, Rogue-Umpqua Divide, present in Abbott Creek RNA
Fritillaria adamantina[2]	Grassy slopes, Diamond Lake, Douglas County
Gentiana newberryi	Alpine meadows, Three Sisters region
Habenaria orbiculata	Moist rich woods, Cascade Range of northern Oregon
Haplopappus hallii[2]	Dry slopes, Columbia River Gorge south; present in Olallie Ridge RNA
Hieracium longiberbe[2]	Rocky bluffs, Columbia River Gorge; Multnomah County, Oregon; and Skamania County, Washington
Hulsea nana	Alpine summits and cinder cones, Cascade peaks
Isopyrum hallii	Moist woods, Cascade Range from Columbia River Gorge to Marion County
Isopyrum stipitatum	Woods at middle altitude, southern Cascades, Douglas to Lake Counties
Lewisia columbiana var. *columbiana*	Open rocky slopes, Columbia River Gorge
Lilium washingtonianum	Open woods at moderate altitude, Cascade Range
Limnanthes floccosa ssp. *bellingeriana*[2]	Rocky flats, southeastern Jackson and southwestern Klamath Counties
Orobanche uniflora f. *inundata*	Sandy River flood plain, Columbia River Gorge
Parnassia fimbriata var. *hoodiana*	Bogs and alpine meadows, vicinity of Mount Hood
Phlox hendersonii	Open rocky slopes, Mount Hood
Pityopus californicus[2]	Deep coniferous woods, west slope of Cascade Range

See footnotes at end of table.

Table 62.--*Vascular plants of special interest in the Western Slopes and Crest Province, Oregon Cascades* (Continued)

Species[1]	Distribution
Poa suksdorfii	High summits of Cascade peaks (also in Wallowa Mountains)
Polygonum cascadense[2]	Mountain meadows, southern Lane County
Polystichum andersonii	Damp ground at mid-elevation, Columbia River Gorge (and along west base of Mount Hood)
Polystichum californicum	Woods and rocky slopes, Cascade (and Siskiyou) Range
Populus tremuloides	Unique population at low elevations and west of Cascade Range on Angels Rest, Columbia River Gorge
Potentilla villosa	Alpine ridges and talus, Mount Hood
Salix fluviatilis[2]	Banks along the Columbia River
Saxifraga bronchialis var. *vespertina*	Wet cliffs, Columbia River Gorge and south in Coast and Cascade Ranges; present in Wildcat Mountain and Olallie Ridge RNA's
Sedum divergens	Rocky alpine slopes present in Wildcat Mountain and Olallie Ridge RNA's
Selaginella douglasii	Cliffs, moist banks, and tree trunks, Columbia River Gorge west to Portland and north to Cowlitz County, Washington
Silene douglasii var. *monantha*	Lower Columbia River Gorge
Silene suksdorfii	High slopes above timberline; Mount Hood, Three Sisters region, Mount Thielsen
Smelowskia ovalis	High altitude in Cascades, Three Sisters north
Sullivantia oregana[2]	Wet cliffs near waterfalls, Columbia River Gorge and lower Willamette River
Synthyris missurica ssp. *hirsuta*[2]	Cascade Range, northern Douglas County
Synthyris missurica var. *stellata*[2]	Moist shady cliffs, Columbia River Gorge
Thelypteris nevadensis	Moist woods, western slopes, Cascade Range (and Siskiyou Mountains)
Vaccinium oxycoccos var. *intermedium*	Sphagnum bogs, Cascade Range south to Marion County (and along coast to Lincoln County)
Viola adunca var. *uncinulata*	Mountain meadows, especially near Crater Lake

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]Species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 63.--*Established Research Natural Areas in the Western Slopes and Crest Province, Oregon Cascades*

Name	Principal features	Agency[1]	Area	
			Ha	Acres
Abbott Creek RNA	Sierran-type mixed conifer forest and stream drainage	FS	1 077	2,660
Bagby RNA	Douglas-fir-western hemlock forests	FS	227	560
Bull Run RNA	Noble fir, Pacific silver fir, and western hemlock forests	FS	146	361
Gold Lake Bog RNA	Subalpine bog communities and permanent ponds	FS	188	463
Olallie Ridge RNA	Subalpine mountain meadows with rich flora and mixed conifer forests	FS	291	720
Wildcat Mountain RNA	Noble fir, Pacific silver fir, and mountain hemlock forests associated with meadow and shrub communities	FS	405	1,000

[1]FS = Forest Service.

Table 64.--*Additional Research Natural Areas needed in the Western Slopes and Crest Province, Oregon Cascades*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic natural areas:						
1. Subalpine forest with lake (Pacific silver fir-western hemlock and western redcedar forests)	T-5,6 A-3,12	Proposed Crabtree Lake RNA	High	BLM	72-82 94-98	0603
2. Old-growth Douglas-fir-western hemlock forest with major stream drainages	T-3,25,6 A-12 R&E-2,3,4,6,7	Proposed Middle Santiam RNA	High	FS	72-80	0605
3. High Cascades subalpine lakes and ponds surrounded by mountain hemlock forest	T-10 A-4,10,7 R&E-5	Near Waldo Lake, Willamette National Forest	Medium	FS	103-106	0901
4. Subalpine forest with major stream drainage	T-6 A-14	Enlargement of Bull Run RNA	Medium	FS	94-98	0607
5. Alpine community mosaic with lake and ponds	T-23 A-5,8,11 R&E-5	Wilderness Area	Low	FS	284-290	0901
Predominantly terrestrial natural areas:						
6. Douglas-fir forest, 100-150 years old in western Cascades	T-1 R&E-3,6,7	Tributary drainage to South Fork of McKenzie River, Willamette National Forest	High	FS	72-88	0605 0606
7. Southwestern Oregon mixed coniferous forest with ash swales	T-13,24	Several areas under consideration in South Umpqua drainage, Umpqua National Forest	High	FS	138-145	0604 0606

See footnotes at end of table.

Table 64.--*Additional Research Natural Areas needed in the Western Slopes and Crest Province, Oregon Cascades* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
8. White fir-Douglas-fir mature forest, High Cascades	T-14	Dead Indian or Lake-of-the-Woods area	High	BLM FS	150-152	0904 0905
9. Maple/talus communities in the Columbia Gorge (with a small waterfall and moist cliffs)	T-27	In a State park, should include a variety of plant species of special interest (table 62)	Low	State FS	91	0601
10. Low-site western hemlock in the northern portion of the High Cascades	T-4	Proposed Abbott Pass area or two-part area (near Timothy Lake and across from Bear Paw Campground), Mount Hood National Forest	High	FS	99	0902
11. Shasta red fir forest in the High Cascades	T-15	Proposed Wickiup Springs RNA	High	FS	155-158	0905
12. High-elevation lodgepole pine with subalpine pumice and ash fields	T-19,26 R&E-5	Crater Lake National Park	Low	NPS	106-108	0901
13. Whitebark pine area	T-17	Crater Lake National Park or Wilderness Area	Low	NPS FS	272-275	0901
14. Mountain meadow-forest mosaic in the southern part of the western Cascades	T-16	Proposed Cougar Butte RNA, Umpqua National Forest	High	FS	152-153	0604
15. Subalpine meadow community mosaic in the High Cascades	T-18 R&E-5	Wilderness area should incorporate most of major communities	Low	FS	269-270	0901
16. Subalpine lava flow	T-20	Between McKenzie and Santiam Highways	Low	FS	300-302	0901

See footnotes at end of table.

Table 64.--*Additional Research Natural Areas needed in the Western Slopes and Crest Province, Oregon Cascades* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
17. Alpine needlegrass	T-22	In southern portion of High Cascades	Medium	FS		0905
18. Green fescue (*Festuca viridula*)	T-21	On east slopes of Mount Hood	Medium	FS	269-272	0901
Predominantly aquatic natural areas:						
19. Low-elevation lake and ponds in Douglas-fir-western hemlock, northern portion	A-1,6,9 R&E-6,7		High	State		0603 0605
20. Low-elevation lake in mixed-conifer forest, southern portion	A-2 R&E-6,7		High	State		0604 0606
21. Hot springs	A-15		High	FS Private		
22. Bulrush-sedge marsh area	A-16		High	FS BLM	108-109	

[1]For a description of these cells see table 59 for terrestrial (T) ecosystems, table 60 for aquatic (A) ecosystems, and table 61 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate those cells which are considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential components.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of the type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. BLM = Bureau of Land Management, FS = Forest Service, NPS = National Park Service.

[4]See appendix V.

EASTERN SLOPES PROVINCE, OREGON CASCADES

The name of this province is really somewhat misleading, since much of it is a high plateau region (fig. 1) dotted with numerous volcanic cones and buttes. Evidence of extensive volcanic activity during Pleistocene and Recent times is abundant. The largest volcanic peak is the Paulina Peak shield volcano which contains Newberry Crater. Pumice, resulting from an eruption of this volcano about 4,000 years ago, mantles an extensive area to the north and east of the crater. Deposits of pumice originating from Mount Mazama in the High Cascades are also widespread and extend from Bend almost to the California border. Broad areas of Pleistocene lava flows are a notable feature in the vicinity of Bend. In addition, outstanding examples of Recent lava flows are situated south of Bend in the Lava Butte area. North of Bend the most abundant rock type is basalt, most of which was laid down during the Miocene. Here volcanic buttes are not as abundant and the most outstanding topographic features are deep, stream-cut canyons.

Virtually all the soils south of Bend are formed in deep deposits of pumice. These soils have immature, regosolic profiles consisting of a moderately thick, loamy coarse sand surface layer with some organic matter accumulation, overlying nearly unweathered, yellow- and buff-colored pumice gravel and sand. Although these soils have high water holding capacities, low soil fertility limits plant root penetration into the largely unweathered pumice; thus many sites appear droughty. North of Bend the soils derived from basalt tend to be shallow and stony and are generally of loam or sandy loam texture.

Although primarily a province of forest ecosystems, major variations in composition and structure of the forests are associated with the rapid decline in annual precipitation eastward from the crest (Franklin and Dyrness 1973). Bunchgrass, sagebrush, and western juniper communities are characteristic of the most arid regions. Ecosystems dominated by a mixture of conifers (ponderosa pine, Douglas-fir, white fir, western larch, and incense-cedar) occupy the main body of the eastern slopes in the north with pure ponderosa pine forests characteristic of the drier, lower fringes. In the south, a region of gentle to flat topography mantled with volcanic pumice, lodgepole pine forests are very extensive and are often associated with large moist meadows. Ponderosa pine stands occur on sloping land forms and white fir forests are encountered at higher elevations. Lava flows and cinder cones provide habitat for distinctive ecosystems in the southern half of the province, and the Columbia River gorge enriches the biotic diversity in the north.

The northern and southern segments of the province also offer major contrasts in aquatic ecosystems. Small streams are relatively common in the north. In the south, however, smaller streams are not common; larger streams and rivers often arise directly from large springs. Large lakes, reservoirs, and marshlands are also abundant in some areas.

Seventeen terrestrial cells have been identified on the eastern slopes of the Oregon Cascade Range (table 65). Nine of these provide for representation of the major forest ecosystems.[2] Three cells focus on juniper, bunchgrass, and sagebrush ecosystems. Special types identified as cells include two in the Columbia River area and two geologically Recent volcanic formations (cinder cone and lava flow).

Eight aquatic cells are listed for the province (table 66). There is no geographic replication, each cell representing a different category of ecosystem—lake, pond, vernal pool, stream, cold spring, hot spring, marsh, and bog.

Research Natural Areas established to fill terrestrial and aquatic cells are expected to include the typical array of plant and animal species. Only two vertebrate animals are listed as rare and endangered cells (table 67). Vascular plants of special interest include 13 species from the Smithsonian list of threatened or endangered plants (table 68).

There are five Federal Research Natural Areas (table 69) plus an additional area (Persia M. Robinson) originally established by the Forest Service and recently given to the Warm Springs Confederation by Congress. These six reserves provide adequate representation of 8 of the 27 terrestrial, aquatic, and animal cells identified in this province; all of the filled cells are terrestrial.

We estimate that 14 additional Research Natural Areas will provide for minimal coverage of the remaining unfilled cells in this province (table 70). Two of the needed tracts combine important terrestrial and aquatic cells—a lake and a stream drainage associated with mixed-conifer forest. Other areas needed include two at the eastern end of the Columbia Gorge for concentrations of plants of special interest.

The Forest Service has lead responsibility for a majority of the required Research Natural Areas (table 70). Assistance from private organizations will almost certainly be necessary in a few cases. Aquatic ecosystems and terrestrial communities on private lands or which represent major timber resources have highest priority for selection and establishment.

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[2] A larger number of cells could be listed to recognize major geographic variations in several forest types. For example, a series of three lodgepole pine/bitterbrush communities (cell No. 5) is necessary to include significant variations in the pumice soils on which the community occurs; differences in the composition, productivity, and management potential of the ecosystem are associated with the soil variability. Existing and proposed Research Natural Areas adequately cover this range in lodgepole pine/bitterbrush communities, however, so we have listed only a single cell. Similar situations exist with terrestrial cell Nos. 3, 4, and 7.

Table 65.--*Terrestrial cells in the Eastern Slopes Province, Oregon Cascades*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Western Juniper Zone:			
1. Western juniper/big sagebrush community	238	Goodlow Mountain RNA	165-167
Ponderosa Pine Zone:			
* 2. Ponderosa pine/western juniper/sagebrush savanna	237	None	160-161 171-180
3. Ponderosa pine/bitterbrush community	237	Metolius, Pringle Falls, Bluejay, and Goodlow Mountain RNA's	171-180
4. Ponderosa pine/manzanita community	237	Metolius and Goodlow Mountain RNA's	171-180
Lodgepole Pine Zone:			
5. Lodgepole pine/bitterbrush community	216	Pringle Falls and Bluejay RNA's; need will be satisfied with establishment of proposed Cannon Wells RNA	187-188
* 6. Lodgepole pine/grass-herb communities on moist sites	216	Token in Pringle Falls RNA, need additional area	187-188
White Fir and Douglas-fir Zones:			
7. Ponderosa pine-Douglas-fir forest	214	Mill Creek, Persia M. Robinson, and Metolius RNA's	191-192
8. Ponderosa pine-white fir/Ross' sedge community	214	Goodlow Mountain RNA	195-196
* 9. Mixed-conifer forest (pine, Douglas-fir, *Abies*). Also, if possible including western larch and incense-cedar	215	Token in Persia M. Robinson and Metolius RNA's, need additional area	190-196
*10. White fir/*Ceanothus* community	213	None	
Steppe and shrub-steppe communities:			
11. Bunchgrass communities		Mill Creek RNA	211-212 215-216
12. Low sagebrush/Sandberg's bluegrass community		Goodlow Mountain RNA	239-241
Special types:			
13. Oregon white oak-grassland communities	233	Mill Creek RNA	
*14. Moist meadows associated with lodgepole pine flats		None	187-190
*15. Eastern Columbia Gorge rock fall with forest complex		None	310-311
*16. Entire undisturbed, forested cinder cone, preferably in *Abies grandis*		None	193-201
*17. Low elevation, Recent lava flow with representative vegetation		None	

*Cells presently lacking adequate representation.

Table 66.--*Aquatic cells in the Eastern Slopes Province, Oregon Cascades*

Cell[1]	Present representation
*1. Lake at moderate elevations surrounded by mixed-conifer forest	None
*2. Permanent subalpine pond	None
*3. Vernal ponds at moderate elevation	None
*4. Large stream drainage at moderate elevations in mixed-conifer forest	None
*5. Large, upwelling cold spring	None
*6. Typical hot spring	None
*7. Marshland	None
*8. Typical bog at mid- to high-elevations	None

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 67.--*Rare and endangered vertebrate animal cells in the Eastern Slopes Province, Oregon Cascades*

Cell	Verified representation	Reference
Amphibians:		
*1. Spotted frog	None	Stebbins 1954 Storm 1966
Mammals:		
*2. Heather vole	None	Bailey 1936 Edwards 1955 Johnson 1973 Maser and Storm 1970 Olterman and Verts 1972 Shaw 1924

*Cells presently lacking adequate representation.

Table 68.--*Vascular plants of special interest in the Eastern Slopes Province, Oregon Cascades*

Species[1]	Distribution
Alisma gramineum var. *gramineum*	Vernal ponds at east end of Columbia River Gorge, near The Dalles and in Klickitat County, Washington
Astragalus applegatei[2]	Moist meadows near Klamath Falls, Klamath County
Astragalus hoodianus	Grassy slopes, Columbia River Gorge, Hood River County, Oregon, and Klickitat County, Washington
Botrychium pumicola[2]	Pumice slopes, Crater Lake and Paulina Mountains
Castilleja applegatei	On pumice, Three Sisters to Crater Lake
Castilleja chlorotica[2]	Mountains, southern Lake County (Gearhart Mountain); Three Sisters
Cicuta bulbifera	Swamps around Klamath Lake
Crepis bakeri ssp. *cusickii*	Dry slopes, Jackson and Lake Counties
Cypripedium montanum	Usually in open woods
Dodecatheon poeticum[2]	Grassland, east end of Columbia River Gorge
Eriogonum prociduum	Volcanic outcrops, Lake County
Eriogonum pyrolaefolium var. *bellingerianum*	Summit of Broken Top Mountain, Deschutes County
Eriogonum umbellatum var. *glaberrimum*	Warner Mountains, southern Lake County
Eriogonum umbellatum var. *hausknechtii*	High mountain meadows
Haplopappus hallii[2]	Dry slopes, east end of Columbia River Gorge
Heuchera grossulariifolia var. *tenuifolia*	Grassy hillsides, east end of Columbia River Gorge
Hydrophyllum capitatum var. *thompsonii*[2]	Near oaks, Columbia River Gorge and Hood River County
Lomatium columbianum	Open rocky slopes, east end of Columbia River Gorge
Lomatium laevigatum[2]	Basaltic slopes, east end of Columbia River Gorge
Lomatium peckianum	Dry hillside and pine woods near Bly, Klamath County
Lomatium suksdorfii[2]	Rocky soil, east end of Columbia River Gorge
Lupinus latifolius var. *thompsonianus*[2]	Dry hillsides, east end of Columbia River Gorge
Mimulus jungermannioides[2]	Moist moss mats, east end of Columbia River Gorge and along lower Deschutes River
Mimulus pulsiferae	Moist open places along eastern base of Cascade Mountains

See footnotes at end of table.

Table 68.--*Vascular plants of special interest in the Eastern Slopes Province, Oregon Cascades* (Continued)

Species[1]	Distribution
Penstemon barrettiae[2]	Basaltic cliffs and talus, east end of Columbia River Gorge
Penstemon euglaucus	Forest openings at middle altitudes, Three Sisters to Mount Hood (Blue Grass Ridge)
Penstemon glandulosus	Rocky slopes, east end of Columbia River Gorge; disjunct to Snake River
Penstemon glaucinus[2]	Pine forest, Gearhart Mountain, Lake County
Penstemon peckii[2]	Open pine woods, eastern base of Cascades, Mount Hood to Three Sisters
Penstemon subserratus	Open woods, eastern slope of Mount Hood, Hood River County
Ribes watsonianum	East side of Mount Hood, Hood River County
Salix laevigata	Along streams, southern Klamath County
Silene nuda ssp. *insectivora*	Along Sprague River, Klamath County
Spiraea pyramidata	Eastern side of Cascade Range
Suksdorfia violacea	Wet cliffs and mossy banks, east end of Columbia River Gorge
Viola adunca var. *cascadensis*	Open pine woods, eastern base of Cascade Range, Deschutes and Jefferson Counties

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]Species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 69.--*Established Research Natural Areas in the Eastern Slopes Province, Oregon Cascades*

Name	Principal features	Agency[1]	Area	
			Ha	Acres
Bluejay RNA	Ponderosa and lodgepole pine on coarse pumice soils	FS	85	210
Goodlow Mountain RNA	Interior ponderosa pine forest and associated ecosystems	FS	510	1,260
Metolius RNA	Interior ponderosa pine forests	FS	583	1,440
Mill Creek RNA	Mosaic of interior mixed conifer and Oregon white oak forest and grass and shrub-steppe	FS	330	815
Persia M. Robinson RNA	Douglas-fir and ponderosa pine forests	WSIR	219	540
Pringle Falls RNA	Lodgepole and ponderosa pine forests on pumice soils	FS	470	1,160

[1]FS = Forest Service, WSIR = Warm Springs Indian Reservation.

Table 70.--*Additional Research Natural Areas needed in the Eastern Slopes Province, Oregon Cascades*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic natural areas:						
1. Mixed-conifer forest (pine, Douglas-fir, and *Abies*) with major stream drainage	T-9,5,10 A-4	Mount Hood National Forest or Sisters area of Deschutes National Forest	High	FS	190-196	0902 0903 0905
2. Mixed-conifer forest (pine, Douglas-fir, and *Abies*) with lake	T-9,5,10 A-1 R&E-1	Deschutes or Winema National Forest at higher elevations than Metolius RNA	High	FS NPS	190-196	0905
3. Moist meadow and associated wet lodgepole pine area, with vernal ponds	T-6,14,5 A-3	Winema National Forest (small representation in Cannon Wells RNA being established)	Medium	FS	187-190	0905
Predominantly terrestrial natural areas:						
4. White fir/*Ceanothus* community, with *Castanopsis*	T-10,4,9	Should be on residual soils, not Mazama pumice	High	FS	176-177 196	0902
5. Lodgepole pine/ bitterbrush community	T-5,14	Cannon Wells RNA being established	High	FS	187-188	0905
6. Ponderosa pine/western juniper/sagebrush savanna	T-2,1,3, 12	Fort Rock or Silver Lake area	High	FS	160-161 171-180	1306
7. Eastern Columbia Gorge rock fall area with forest complex	T-15,7,9, 13	Hood River area. May contain a variety of plants of special interest (table 68)	Medium	FS	310-311	0904
8. Entire undisturbed, forested cinder cone, preferably in *Abies grandis* zone	T-16	Graham Butte, west of Sisters	High	FS	193-201	0905
9. Low-elevation, recent lava flow with representative vegetation	T-17	Lava Butte area	Medium	FS		0905

See footnotes at end of table.

Table 70.--*Additional Research Natural Areas needed in the Eastern Slopes Province, Oregon Cascades* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Predominantly aquatic natural areas:						
10. Subalpine permanent ponds and bog area	A-2,8 R&E-1	Just east of Santiam Pass (south of highway) is possible location	Medium	FS	108-109	0901
11. Large, upwelling cold spring	A-5 R&E-1	Headwaters of the Metolius River	Medium	FS Private		0905
12. Typical hot spring	A-6		High	FS Private		
13. Marshland	A-7	Enlargement of Pringle Falls RNA will at least partially fill this need	High	FS		0905
Natural area for protection of vascular plants of special interest:						
14. An area near the eastern end of the Columbia River Gorge for the protection of vascular plant species of special interest		Private land near Mosier, Oregon. Species to be protected include *Lomatium columbianum, L. laevigatum, L. suksdorfii, Dodecatheon poeticum, Penstemon barrettiae, Orobanche uniflora,* and *Artemisia lindlegana*	High	Private		0904

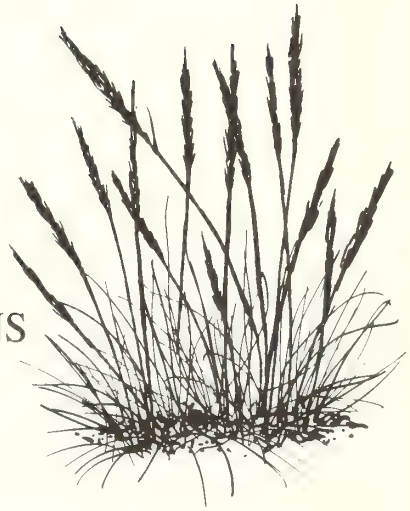
[1]For a description of these cells see table 65 for terrestrial (T) ecosystems, table 66 for aquatic (A) ecosystems, and table 67 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate those cells which are considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential components.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of that type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. FS = Forest Service, NPS = National Park Service.

[4]See appendix V.

HOCO, BLUE, AND WALLOWA MOUNTAINS OVINCE, NORTHEASTERN OREGON D SOUTHEASTERN WASHINGTON



This province is made up of three principal mountain ranges separated by faulted valleys and synclinal basins (fig. 1). Relief is highly variable; moderate slopes are common in the Ochoco and Blue Mountains, whereas the heavily glaciated Wallowa Mountains have a much higher proportion of steep slopes. Maximum elevations range from about 2100 m in the Ochocos to 2900 at Eagle Cap in the Wallowas. Valley floor elevations are about 750 m in the Ochocos and 900 m in the broad basin between the Blue and Wallowa Mountains. Spectacular Hells Canyon, 1660 m deep, comprises the eastern boundary of the province.

Geologically, the province is separated into eastern and western units, with the dividing line just east of John Day. The western unit contains some of the oldest rocks in Oregon which include Paleozoic to Jurassic formations of conglomerate, sandstone, siltstone, shale, and limestone. In addition, Columbia River basalt, extruded during the Miocene, occupies large areas within the western Blue Mountains and also extends into the eastern section where it forms the major portion of the northern slopes. The eastern portion of the province was subjected to considerable alpine glaciation during the Pleistocene, as indicated by numerous cirques, glacial lakes, and moraines. Bedrock in the Wallowa Mountains is largely made up of Triassic sedimentary formations (sandstone, siltstone, shale, and limestone) and granitic intrusions.

During the late Pleistocene, much of the area within the central and northern portions of the Blue Mountains was covered by a layer of volcanic ash and fine pumice. Subsequent erosion has largely removed the ash from south-facing slopes; however, other locations are typically mantled by the material. In addition, many upland areas, especially in the eastern portion, are mantled by loess deposits.

Obviously, with such a wide range of parent materials, vegetation, and climate, soils within the province are highly variable and only a few of the major types will be mentioned. Forested soils derived from volcanic ash are poorly developed, generally dark brown in color, and fine sandy loam to silt loam in texture. Forested soils in loess deposits are generally Brown Podzolics, having deep, silt-textured profiles. The most widespread soils supporting grassland and shrub-grassland vegetation are classed as Prairie soils and Chernozems. These vary in texture depending on parent material, but are generally silt loam to clay loam, with fine-textured B horizons.

Since three major mountain blocks and a wide range of elevations are present in this province, there is a relatively large number of ecosystems represented as well as considerable variation in those ecosystems. Mixed-conifer forests (Douglas-fir, grand fir, ponderosa and western white pines, and western larch) dominate the landscape, with ponderosa pine and western juniper communities on more arid habitats and Engelmann spruce-subalpine fir forests on cool, moist subalpine areas. Subalpine and alpine meadow communities occur on the highest ridges and summits, and grassland and sagebrush ecosystems are common at low elevations, particularly in the canyons of the Snake River and its tributaries. Streams, lakes, and ponds of various types are well represented in the province.

Twenty-five terrestrial cells have been identified (table 71). Eleven of these provide for representation of the principal forest ecosystems. The remainder are equally divided between steppe and shrub-steppe ecosystems and mountain meadows of various types.

Nine of the 13 identified aquatic cells (table 72) provide for representation of lakes, ponds, and vernal pools in three elevational zones—montane, subalpine, and alpine. Two stream drainages, one each in subalpine and montane environments, are viewed as essential cells in a natural area system. A marsh and bog complete the list.

It is presumed that areas established for terrestrial and aquatic cells will include the array of plant and animal species typical of those ecosystems. Five vertebrate animal species have been identified which should receive specific consideration in selection of Research Natural Areas because of their rare or endangered status (table 73). There are many vascular plants of special interest including 30 listed as threatened or endangered on the Smithsonian list (table 74). The greatest concentration of these is in the Snake River Canyon. Many of the remaining species occur on subalpine and alpine habitats, particularly in the Wallowa Mountains. Nineteen of the species listed by the Smithsonian Institution are accounted for between the Snake River Canyon and alpine reaches of the Wallowa Mountains.

Four Federal Research Natural Areas have been established within the province (table 75). These provide adequate coverage for 6 of the 43 cells identified for this province; all of the filled cells are terrestrial. Substantial populations of many of the special interest plants are undoubtedly already protected within the Eagle Cap and Strawberry Mountain Wilderness and in other scenic reserves along the Snake River.

There is a need for 18 additional Research Natural Areas for minimal representation of all identified terrestrial, aquatic, and animal cells (table 76). Two of the largest areas should be major stream drainages with associated mixed-conifer forest; three other areas should combine essential terrestrial and aquatic cells. Most of the remaining areas focus on a single terrestrial or aquatic ecosystem or, in a few cases, an intricate mosaic of terrestrial ecosystems. One area is needed in the Snake River Canyon (need No. 14) which incorporates several distinctive communities as well as habitat for a variety of special interest plant species.

The responsibility for establishment of the necessary Research Natural Areas lies almost entirely with the Forest Service (table 76). Bureau of Land Management is lead agency for two aquatic areas, although it is not certain that a lake and a bog suitable for designation as Research Natural Areas exist. Highest priority is given selection of natural areas representing commercial forest types and low elevation aquatic ecosystems.

Table 71.--*Terrestrial cells in the Ochoco, Blue, and Wallowa Mountains Province, northeastern Oregon and southeastern Washington*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Western Juniper Zone:			
1. Western juniper/bluebunch wheatgrass community	238	Ochoco Divide and Canyon Creek RNA's	165-167
Ponderosa Pine Zone:			
* 2. Ponderosa pine/bunchgrass communities in the northern Blue Mountains	237	None	171-176
* 3. Ponderosa pine/bitterbrush/bunchgrass communities	237	None	175
Douglas-fir Zone:			
4. Ponderosa pine/pinegrass community	237	Ochoco Divide and Canyon Creek RNA's	175-176 191-192
5. Douglas-fir-ponderosa pine/pinegrass community	214	Ochoco Divide and Canyon Creek RNA's	191-192
* 6. Douglas-fir-ponderosa pine/shrub community	214	None, proposed Moore Flat RNA may fill need	191-192
Grand Fir Zone:			
7. Mixed-conifer forest with western larch dominance	213	Rainbow Creek RNA	195-199
8. Mixed-conifer forest with western white pine dominance	215	Rainbow Creek RNA	195-199
* 9. Grand fir/thinleaf huckleberry community	213	Some representation on Rainbow Creek and Pataha Bunchgrass RNA's, need additional area	196
Subalpine Fir Zone:			
*10. Engelmann spruce-subalpine fir forest	206	None	205-206
Steppe communities:			
11. Bluebunch wheatgrass-Sandberg's bluegrass community		Rainbow Creek RNA	226
*12. Idaho fescue-bluebunch wheatgrass community		Present in Pataha Bunchgrass RNA, need additional area at higher elevations in Blue or Wallowa Mountains	219-220

See footnote at end of table.

Table 71.--*Terrestrial cells in the Ochoco, Blue, and Wallowa Mountains Province, northeastern Oregon and southeastern Washington* (Continued)

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Steppe communities: (Continued)			
*13. Sandberg's bluegrass-onespike oatgrass community		None	245
*14. *Sporobolus cryptandrus/Poa sandbergii* and *Aristida longiseta/Poa sandbergii* associations along the Snake River		None	228-229
Shrub-steppe communities:			
*15. Big sagebrush/bunchgrass community inside forest zone		None	216-219
*16. Low sagebrush/bunchgrass community inside forest zone		None	239-241
*17. Rigid sagebrush scabland		None	242
Subalpine and alpine meadow communities:			
*18. Alpine Idaho fescue community		None	
*19. Green fescue community in the Wallowa Mountains		None	271-272
*20. Alpine sagebrush community in the Blue Mountains		None	
*21. Black sedge community in the Wallowa Mountains		None	271-272
Special types:			
*22. Lodgepole pine/dwarf huckleberry/pinegrass community in the Blue Mountains (with minimal fir regeneration)	218	None	197-198
*23. Moist bluegrass meadow in the Blue Mountains		None	199-200
*24. Moist bluegrass meadow in the Wallowa Mountains		None	199-200
*25. Typical wet meadow (tufted hairgrass and sedges)		None	199-201

*Cells presently lacking adequate representation.

Table 72.--*Aquatic cells in the Ochoco, Blue, and Wallowa Mountains Province, northeastern Oregon and southeastern Washington*

Cell[1]	Present representation
* 1. Low-elevation lake surrounded by mixed-conifer forest	None
* 2. Typical subalpine lake	None
* 3. Alpine lake	None
* 4. Permanent ponds at low elevations	None
* 5. Subalpine permanent ponds	None
* 6. Alpine permanent ponds	None
* 7. Vernal ponds at low elevation	None
* 8. Subalpine vernal ponds	None
* 9. Alpine vernal ponds	None
*10. Large stream drainage in mixed-conifer forest	None
*11. Large subalpine stream drainage	None
*12. Marshland	None
*13. Typical bog	None

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 73.--*Rare and endangered vertebrate animal cells in the Ochoco, Blue, and Wallowa Mountains Province, northeastern Oregon and southeastern Washington*

Cell	Verified representation	Reference
Fish:		
*1. Malheur sculpin	None	Bond 1966
Amphibians:		
*2. Tailed frog	None	Stebbins 1954 Storm 1966
Mammals:		
*3. Malheur or Preble shrew	None	Bailey 1936 Olterman and Verts 1972
*4. Washington squirrel	None	Bailey 1936 Olterman and Verts 1972
*5. Heather vole	None	Bailey 1936 Edwards 1955 Johnson 1973 Maser and Storm 1970 Olterman and Verts 1972 Shaw 1924

*Cells presently lacking adequate representation.

Table 74.--*Vascular plants of special interest in the Ochoco, Blue, and Wallowa Mountains Province, northeastern Oregon and southeastern Washington*

Species[1]	Distribution
Allium madidum[2]	Seasonally wet meadows, Blue Mountains
Aquilegia flavescens	Alpine meadows, Wallowa Mountains
Asplenium viride	Moist cliffs, especially on limestone, Wallowa Mountains
Astragalus arthurii	Arid slopes, Blue and Wallowa Mountains, Wallowa and Umatilla Counties
Astragalus cusickii var. *cusickii*	Snake River canyon and tributaries from west, Baker and Wallowa Counties
Astragalus robbinsii var. *alpiniformis*[2]	Alpine stream banks, high peaks of Wallowa Mountains
Astragalus vallaris	Snake River canyon, Wallowa County
Balsamorhiza hirsuta	Dry plains, Union County (Grande Ronde prairie)
Botrychium boreale	Deep mossy woods, Wallowa Mountains
Botrychium lanceolatum	Alpine slopes, Wallowa Mountains
Botrychium virginianum	Moist rich woods, Wallowa Mountains
Calochortus longibarbatus var. *peckii*	Meadows, Ochoco Mountains, Crook County
Calochortus nitidus	Open slopes, Blue Mountains
Camassia cusickii[2]	Seeps in canyons along Pine Creek, Baker County, to Snake River
Campanula sacajaweana[2]	Stony alpine slopes, Wallowa Mountains
Carex concinna	Coniferous woods, Hurricane Creek canyon, Wallowa County
Carex limnophila	Moist places at mid-elevation, Wallowa Mountains
Castilleja chrysantha[2]	Alpine meadows, Wallowa and Blue Mountains
Castilleja fraterna[2]	Willow thickets, alpine meadows, Wallowa Mountains
Castilleja glandulifera[2]	Rocky slopes, Blue Mountains
Castilleja oresbia[2]	Endemic in Blue Mountains where it is common on stony soils with stiff sagebrush
Castilleja ownbeyana[2]	Alpine meadows, Wallowa Mountains
Castilleja rubida	Alpine summits, Wallowa Mountains
Chaenactis cusickii	Sandy hills, Baker and Malheur Counties
Cheilanthes feei	Cliff crevices, Snake River canyon
Claytonia megarhiza var. *bellidifolia*[2]	Talus slopes at high altitude, Blue and Wallowa Mountains
Corallorhiza trifida	Deep moist woods, Wallowa Mountains
Cryptogramma stelleri	Moist shaded cliffs, Wallowa Mountains
Draba lemmonii var. *cyclomorpha*[2]	High peaks of Wallowa Mountains
Dryas drummondii	Rocky slopes and summits, Wallowa Mountains
Dryas octopetala var. *hookeriana*	Alpine peaks, Wallowa Mountains
Dryopteris filix-mas	Moist woods, northeastern Oregon
Erigeron disparipilus	Snake River canyon
Eriogonum scopulorum	High ridges, Wallowa Mountains
Eritrichium nanum	High rocky slopes, Wallowa Mountains

See footnotes at end of table.

Table 74.--*Vascular plants of special interest in the Ochoco, Blue, and Wallowa Mountains Province, northeastern Oregon and southeastern Washington* (Continued)

Species[1]	Distribution
Geum gracilipes	Moist cliff, head of Anthony Creek, Baker County
Habenaria obtusata	Open woods, Hurricane Creek canyon, Wallowa County
Hackelia hispida[2]	Cliffs and talus slopes, Snake River canyon
Haplopappus radiatus[2]	Dry hillsides in and near Snake River canyon
Hedysarum boreale var. *boreale*	Wallowa Mountains
Heuchera grossulariifolia var. *grossulariifolia*	Cliffs, Baker and Wallowa Counties
Hulsea algida	Talus slopes, especially in granitic sand, Wallowa Mountains
Kobresia bellardii	Alpine ridges, Wallowa Mountains
Kobresia simpliciuscula	Banks of Hurricane Creek, Wallowa County
Leptodactylon hazelae[2]	Dry rocky slopes of Hells Canyon, Snake River
Lesquerella sherwoodii	High slopes of Wallowa Mountains
Lewisia columbiana var. *wallowensis*[2]	Rocky slopes, Wallowa Mountains
Lomatium cusickii	Alpine ridges, Wallowa Mountains
Lomatium greenmanii[2]	Rocky ridges, head of Keystone Creek, Wallowa Mountains
Lomatium oreganum[2]	Rocky ridges, Blue and Wallowa Mountains
Lomatium rollinsii[2]	Open slopes, Snake River canyon, Wallowa County
Lomatium salmoniflorum	Basaltic slopes, Snake River canyon, Wallowa County
Lomatium serpentinum[2]	Dry rocky slopes, Snake River canyon
Lomatium watsonii	Dry slopes, Blue Mountains (also Jefferson and Wasco Counties)
Lupinus sabinii[2]	Endemic in Blue Mountains at high elevation but locally common there
Mimulus clivicola	South end of Snake River canyon
Mirabilis macfarlanei[2]	Snake River canyon, Wallowa County
Nemophila kirtleyi	Shady banks, Snake River canyon and tributaries, Wallowa and Baker Counties
Oryzopsis hendersonii	Sagebrush, Ochoco National Forest, Jefferson County
Pedicularis bracteosa var. *pachyrhiza*	Coniferous forest, Blue and Wallowa Mountains
Pediocactus simpsonii var. *robustior*	Arid areas, Wallowa County
Pellaea breweri	Open granite slopes, Wallowa Mountains
Pellaea bridgesii	Granite slopes at high altitude, Wallowa Mountains
Penstemon elegantulus[2]	Grassland overlooking Snake River canyon, Wallowa County
Penstemon fruticosus var. *serratus*	Mountains east of Imnaha River, Wallowa County
Penstemon payettensis	Open slopes in well-drained soil, Wallowa Mountains
Penstemon spathulatus[2]	High rocky slopes, Wallowa Mountains
Penstemon triphyllus	Dry hills, Snake River and tributaries, Baker and Wallowa Counties

See footnotes at end of table.

Table 74.--*Vascular plants of special interest in the Ochoco, Blue, and Wallowa Mountains Province, northeastern Oregon and southeastern Washington* (Continued)

Species[1]	Distribution
Phacelia minutissima	Damp ground at mid-elevation, Wallowa Mountains
Phlox colubrina	Rocky banks, Snake River and lower Imnaha River canyons
Pinus flexilis	High slopes, Wallowa Mountains
Pleuropogon oreganus	Blue Mountains
Polystichum kruckebergii[2]	Rocky open slopes, Wallowa Mountains and Snake River canyon
Primula cusickiana[2]	Rocky slopes, Wallowa Mountains
Ranunculus oresterus	Swales, Blue Mountains, eastern Grant and Union Counties
Ribes cereum var. *colubrinum*	Snake River canyon, Wallowa County
Ribes irriguum	Streambanks in Blue Mountains, northeastern Oregon
Rubus bartonianus[2]	Rocky slopes, Snake River canyon, Wallowa County
Salix arctica	Alpine summits, Wallowa Mountains
Salix brachycarpa	Moist places at high altitude, Wallowa Mountains
Salix drummondiana	Stream banks and meadows, Wallowa Mountains (and Steens Mountains)
Salix vestita	High peaks, Wallowa Mountains
Salix wolfii var. *idahoensis*	Stream banks and moist ground, high altitude in Wallowa Mountains
Saxifraga adscendens	High alpine meadows, Wallowa Mountains
Saxifraga oppositifolia	Alpine scree, Wallowa Mountains
Selaginella watsonii	Exposed rocky sites, Wallowa Mountains
Senecio porteri[2]	Open rocky peaks, Wallowa Mountains
Silene spaldingii[2]	Sagebrush and pine forest, Wallowa and Union Counties
Smelowskia calycina	Alpine slopes in Wallowa Mountains
Thalictrum alpinum var. *hebetum*	Alpine meadows, Wallowa Mountains
Thelypodium eucosmum[2]	Lower canyons, Blue Mountains of Grant, Baker, and Wheeler Counties
Tonella floribunda	Snake River canyon and Pine Creek, Wallowa and Baker Counties
Townsendia parryi	Subalpine ridges of Wallowa Mountains
Trifolium plumosum var. *plumosum*[2]	Endemic in Blue Mountains but common there
Viola adunca var. *bellidifolia*	Wet meadows, Wallowa (and Cascade) Mountains
Viola canadensis var. *rugulosa*	Woods of Imnaha and Snake River canyons

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]Species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 75.--*Established Research Natural Areas in the Ochoco, Blue, and Wallowa Mountains Province, northeastern Oregon and southeastern Washington*

Name	Principal features	Agency[1]	Area	
			Ha	Acres
Canyon Creek RNA	Interior ponderosa pine forest (Washington)	FS	283	700
Ochoco Divide RNA	Ponderosa pine-Douglas-fir and grand fir-western larch-Douglas-fir forests (Oregon)	FS	777	1,920
Pataha Bunch-grass RNA	Bluebunch wheatgrass stands (Washington)	FS	21	51
Rainbow Creek RNA	Interior mixed conifer forest with abundant western white pine (Oregon)	FS	170	420

[1]FS = Forest Service.

Table 76.--*Additional Research Natural Areas needed in the Ochoco, Blue, and Wallowa Mountains Province, northeastern Oregon and southeastern Washington*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic natural areas:						
1. Mixed-conifer forest and major stream drainage extending from moderate elevations into the subalpine	T-10,22,25 2,3,4,5, 6,7,8 A-11,12 R&E-2,3	Ideally should have a range 2,000 to 6,000 feet in elevation. Possibly could enlarge Rainbow Creek RNA sufficiently to fill this need	Medium	FS	190-196 204-206	1201
2. Juniper, pine, mixed conifer, and meadow vegetation with large stream drainage	T-1,2,3,4, 5,7,17,25 A-10 R&E-1	Headwaters area of Silver Creek, Snow Mountain District, Ochoco National Forest	Medium	FS	165-167 171-180 195-201	1204 1208
3. Grand fir/thinleaf huckleberry community and marsh area	T-9,10,22, 25 A-12	Central Blue Mountains	High	FS	195-196	1204 1206
4. Green fescue, alpine sagebrush, and black sedge communities with headwaters of stream in the Wallowa Mountains	T-19,20,21 10 A-11 R&E-2	Hurricane Creek in Eagle Cap Wilderness Area. Should contain several plant species of special interest (table 74)	Medium	FS	207-208 271-272	1701
5. Mixed-conifer forest with lake and/or permanent pond	T-6,7,8, 9,25 A-2,5,8 12	Possibly in Strawberry Mountain or Eagle Cap Wilderness Area	Low	FS	190-196 204-206	1205 1701
Predominantly terrestrial natural areas:						
6. Ponderosa pine/ bunchgrass communities	T-2,4,5, 12,13	Starkey Experimental Range is possible location	High	FS	171-176	1206

See footnotes at end of table.

Table 76.--*Additional Research Natural Areas needed in the Ochoco, Blue, and Wallowa Mountains Province, northeastern Oregon and southeastern Washington* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
7. Ponderosa pine/ bitterbrush/bunchgrass, big sagebrush/ bunchgrass, and low sagebrush/bunchgrass communities	T-3,15,16	Southern Blue Mountains	High	FS	171-180 183-184	1206 1208
8. Alpine Idaho fescue community	T-18,20,9, 10,22	Malheur National Forest-Field Creek, Brady Mountains. Also in Strawberry Mountain Wilderness Area	Low	FS		1205
9. Moist bluegrass meadow in Blue Mountains	T-23,4,5, 9		Medium	FS	199-200	1206 1208
10. Moist bluegrass meadow in Wallowa Mountains	T-24,4,5, 9		Medium	FS	199-200	1702 1703
11. Idaho fescue/bluebunch wheatgrass community	T-12,2	Blue or Wallowa Mountains. Should be at higher elevation than Pataha Bunchgrass RNA	Medium	FS	244	1203 1703
12. Sandberg's bluegrass- onespike oatgrass community	T-13,2,4, 5,12	Starkey Experimental Range is possible location	Medium	FS	245	1206
13. Rigid sagebrush scabland	T-17,3,4, 5,15,16	Southern Blue Mountains (Ochoco or Malheur National Forest)	Medium	FS	242	1208

See footnotes at end of table.

Table 76.--*Additional Research Natural Areas needed in the Ochoco, Blue, and Wallowa Mountains Province, northeastern Oregon and southeastern Washington* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
14. *Sporobolus cryptandrus/ Poa sandbergii* and *Aristida longiseta/P. sandbergii* associations along the Snake River	T-14,2,15 R&E-4	Southern Snake River Canyon--should have elevational range of 800 to 3,000 feet. Should contain a variety of plant species of special interest (table 74)	Medium	FS	228-229	1211
Predominantly aquatic natural areas:						
15. Low-elevation lake and ponds	A-1,4,7	May be difficult to find	High	BLM		1201 1208
16. Alpine lake and ponds	A-3,6,9 R&E-2,5	Eagle Cap Wilderness Area	Medium	FS		1701
17. Typical bog area	A-13	May not be available	High	BLM FS		
18. Tule marsh	A-12	Suitable area may occur in Ladd Marsh refuge	High	OSFWC		1201

[1] For a description of these cells see table 71 for terrestrial (T) ecosystems, table 72 for aquatic (A) ecosystems, and table 73 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate cells considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential.

[2] Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of that type will be lost to other uses. Acquisition urgency.

[3] Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. BLM = Bureau of Land Management, FS = Forest Service, OSFWC = Oregon State Fish and Wildlife Commission.

[4] See appendix V.

BASIN AND RANGE PROVINCE, EASTERN OREGON

The Basin and Range Province (fig. 1) is characterized by a series of fault-block mountains enclosing basins with internal drainage. Elevations range from about 1200 m to 2930 m atop Steens Mountain. Except for the precipitous fault scarps (e.g., Winter Rim and Abert Rim), much of the area is gently rolling with low relief. Since annual precipitation in the area averages only 180 to 300 mm, most streams are intermittent, and numerous undrained basins contain shallow, saline lakes.

Virtually all of the rocks which outcrop in the province date from Miocene to Recent epochs. Most of the rock types present are igneous, with basalt and andesite being the most common. Other rocks of more minor occurrence include rhyolite, dacite, tuffs, and tuffaceous sedimentaries. Evidences of glaciation are confined to Steens Mountain where most channels are glacially carved and contain cirques at their head.

Soils developed on basic igneous rocks under grass-shrub vegetation commonly have a very stony loam surface horizon underlain by a clay or stony loam subsoil. In some locations these soils have a silica-cemented hardpan at depths of 2 to 5 dm.

Shrub-steppe ecosystems dominated by various species of sagebrush and bunchgrasses are most characteristic (Franklin and Dyrness 1973). Desert or salt desert shrub communities of shadscale, salt sage, greasewood, and similar species occupy low-lying areas with saline or alkali soils. Western juniper, mountain mahogany, and along the province's western margin, ponderosa pine typify savanna ecosystems which are present. Steens Mountain adds substantial biotic diversity to the province; alpine ecosystems are found on the summit; and a variety of ecosystems, notably quaking aspen and western juniper woodlands, clothe much of the slopes. Permanent and vernal ponds and lakes of varying salinity are the most characteristic aquatic ecosystems.

Of the 19 terrestrial cells identified (table 77), over half provide for representation of the distinctive sagebrush and desert shrub ecosystems. Five major savanna communities and several ecosystems confined to Steens Mountain are also listed.

Of the 14 aquatic cells, 9 identify ponds and lakes in a variety of environments (desert to subalpine) and include both fresh and saline types (table 78). One stream ecosystem on Steens Mountain and a tule marsh on the western edge of the province are also considered essential elements.

Areas to be established for terrestrial and aquatic cells are expected to include the array of plant and animal species typical of these ecosystems. Ten vertebrate animal species are recognized specifically as cells because of their rare or endangered status (table 79); 3 of these are fish. Vascular plants of special interest include eight from the Smithsonian list of threatened and endangered plants (table 80); several of these are on Steens Mountain.

There are no established Research Natural Areas in the Basin and Range Province, although several are being considered on Steens Mountain. At least 10 areas will be required to provide minimal representation of the 43 identified terrestrial, aquatic, and animal cells (table 81). Several of the proposed Research Natural Areas (see Nos. 1, 2, 4, and 5) incorporate five to seven cells and, unless the selected areas are very large, inclusion of this many elements may not be possible. Consequently, more natural areas may actually prove necessary. In any case, most of the Research Natural Areas will include ecosystem mosaics in mountain and basin habitats.

The Bureau of Land Management is expected to carry most of the lead responsibility in this province with some contribution from Fish and Wildlife Service, State agencies, and the private sector (table 81).

Table 77.--*Terrestrial cells in the Basin and Range Province, eastern Oregon*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Ponderosa pine and western juniper communities:			
* 1. Ponderosa pine/bitterbrush/Idaho fescue savanna	237	None	176-180
* 2. Western juniper/big sagebrush/bluebunch wheatgrass community	238	None	165-167
* 3. Western juniper/big sagebrush-bitterbrush community	238	None	165-167
* 4. Western juniper/bluebunch wheatgrass community	238	None	165-167
Sagebrush communities:			
* 5. *Artemisia tridentata/Agropyron spicatum* community		None	236-237
* 6. *Artemisia tridentata/Festuca idahoensis* community		None	238
* 7. *Artemisia arbuscula/Agropyron spicatum* community		None	239-241
* 8. *Artemisia arbuscula/Festuca idahoensis* community		None	239-241
* 9. *Artemisia cana* community		None	242
*10. *Artemisia arbuscula/Danthonia unispicata/ Koeleria cristata* communities in Silver Lake area		None	239-241
*11. Big sagebrush-bitterbrush/Idaho fescue community		None	238-239
Desert or salt desert shrub communities:			
*12. Salt desert shrub, desert shrub shadscale, salt sage, greasewood communities, with full range of shrub and shrub/grass communities on saline and alkali soils (dominants are *Atriplex confertifolia, A. nuttallii, Sarcobatus, Distichlis, Elymus*, and *Artemisia spinescens)*		None	245
*13. *Grayia spinosa* community		None	245
*14. *Eurotia lanata* community		None	245
Other shrub communities:			
*15. *Cercocarpus* (mountain mahogany) community		None	243-244
*16. Bitterbrush/bunchgrass community		None	244
Special types:			
*17. Aspen type on Steens Mountain	217	None	245-246
*18. Alpine communities on Steens Mountain		None	
*19. Outlying stand of white fir, Steens Mountain		None	

*Cells presently lacking adequate representation.

Table 78.--*Aquatic cells in the Basin and Range Province, eastern Oregon*

Cell[1]	Present representation
* 1. Low-elevation saline lake in a desert setting	None
* 2. Low-elevation playa lake	None
* 3. Low-elevation freshwater lake	None
* 4. Subalpine lake in the Steens Mountain area	None
* 5. Low-elevation, permanent saline ponds	None
* 6. Low-elevation, permanent freshwater ponds	None
* 7. Subalpine permanent ponds in the Steens Mountain area	None
* 8. Typical vernal pond or marsh area adjacent to a playa lake	None
* 9. Typical subalpine vernal pond	None
*10. Subalpine stream drainage in the Steens Mountain area	None
*11. Tule marsh in the western portion of the province	None
*12. Typical low-elevation stream drainage	None
*13. Typical hot springs	None
*14. Typical cold springs	None

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 79.--*Rare and endangered vertebrate animal cells in the Basin and Range Province, eastern Oregon*

Cell	Verified representation	Reference
Fish:		
* 1. California roach	None	Bond 1966
* 2. Lahontan redside	None	Bond 1966
* 3. Tahoe sucker	None	Bond 1966
Birds:		
* 4. Western burrowing owl	None	Gabrielson and Jewett 1940
Mammals:		
* 5. Malheur or Preble shrew	None	Bailey 1936 Hansen 1956 Olterman and Verts 1972
* 6. Merriam shrew	None	Bailey 1936 Hansen 1956 Johnson and Clanton 1954 Olterman and Verts 1972
* 7. Pygmy rabbit	None	Bailey 1936 Hansen 1956 Olterman and Verts 1972
* 8. White-tailed jack rabbit	None	Bailey 1936 Hansen 1956 Olterman and Verts 1972
* 9. Northern grasshopper mouse	None	Bailey 1936 Hansen 1956
*10. Sagebrush vole	None	Bailey 1936 Clanton et al. 1971 Hansen 1956 Johnson et al. 1948 Maser et al. 1974 Olterman and Verts 1972

*Cells presently lacking adequate representation.

Table 80.--*Vascular plants of special interest in the Basin and Range Province, eastern Oregon*

Species[1]	Distribution
Agastache cusickii	Known only from Steens Mountain, Harney County
Allium punctum	Stony flats along Blitzen River, Harney County
Astragalus alvordensis[2]	Sandy plains and hills, southern Harney and Malheur Counties (Alvord Valley)
Castilleja steensensis[2]	Steens Mountain, Harney County
Cirsium peckii	Streambanks, eastern slopes of Steens and Pueblo Mountains, Harney County
Claytonia nevadensis	Steens Mountain, Harney County
Claytonia umbellata	Steens Mountain, Harney County
Cymopterus bipinnatus	Dry slopes, Steens Mountain, Harney County
Draba sphaeroides var. *cusickii*[2]	Steens Mountain
Ephedra nevadensis	Open gravelly flats, Pueblo Mountains; near Oregon-Nevada border
Ephedra viridis	Dry ridges, southern Harney County near Nevada border
Eriogonum chrysops[2]	Alpine slopes, Steens Mountain, Harney County
Eriogonum cusickii[2]	Rocky sagebrush areas
Eriogonum umbellatum var. *hausknechtii*	Steens Mountain
Lupinus biddlei[2]	Dry plains, southern Harney and Malheur Counties
Pleuropogon oreganus	Swampy ground, Lake and Union Counties
Potamogeton diversifolius	Ponds, Steens Mountain, Harney County
Ranunculus andersonii	Sagebrush desert and ponderosa pine forest; southern Lake County and southern Malheur County
Rhysopterus plurijugus[2]	On diatomite, Malheur, Harney, and eastern Lake Counties
Salix drummondiana	Streambanks and most meadows in mountains; Steens Mountain, Harney County (and Wallowa Mountains)
Sedum debile	Rocky ledges to alpine talus slopes; Steens Mountain
Senecio werneriaefolius	Steens Mountain, Harney County at high elevation
Thelypodium brachycarpum[2]	Low, chiefly alkaline areas, southeast Oregon

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]Species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 81.--*Research Natural Areas needed in the Basin and Range Province, eastern Oregon*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic natural areas:						
1. Large area on Steens Mountain. To include juniper/sage, juniper/bluebunch wheatgrass, aspen, alpine communities, a large stream drainage, and ponds (also lake, if available)	T-2,4,17, 18 A-7,9,10 4 R&E-1,2,3, 5	3-Mile Creek or Trout Creek drainages. Elevation range should be from 6,000 to 8,000 feet. May also include some plant species of special interest (table 80)	Medium	BLM State	165-167 246 249 271-272	1501 1505
2. A variety of big sagebrush and low sagebrush communities plus a small freshwater lake	T-5,6,7, 8,9 A-3 R&E-1,2,3	Warner Valley area	Medium	BLM FWS	234-242	1506 1507
3. Playa lake, vernal pond, or marsh, with *Artemisia cana* community	T-9,12,13 14 A-2,8		Medium	BLM State FWS	234 242	1502
4. Saline lake and ponds; salt desert shrub, desert shrub, shadscale, salt sage, and greasewood communities; *Grayia spinosa* community; and *Eurotia lanata* community	T-12,13,14 A-1,5 R&E-6	Borax Lake in the Alvord Desert and surrounding area	Medium	BLM Private	245	1502 1506
Predominantly terrestrial natural areas:						
5. Big sagebrush/bitterbrush/ Idaho fescue community interspersed with areas of ponderosa pine/bitterbrush/ Idaho fescue savanna. Also should include at least small areas of mountain mahogany, low sagebrush, and juniper communities	T-1,3,10 11,15,16 7,8 R&E-6,7,8 9,10	Located from Silver Lake area southward	High	BLM FS Private	176-179 238-244	1507 1508

See footnotes at end of table.

Table 81.--*Research Natural Areas needed in the Basin and Range Province, eastern Oregon* (Continued)

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
6. Outlying stand of white fir	T-19	Steens Mountain	Medium	Private BLM		1501
Predominantly aquatic natural areas:						
7. Tule marsh area	A-11	Klamath Marsh or Sycan Marsh are possible locations	High	Private FWS State		1405
8. Low-elevation stream drainage	A-12	Silver Creek (may be difficult to find suitable area)	High	Private FWS		1507 1508
9. Hot springs	A-13	Alvord Desert	High	BLM Private		1502
10. Cold springs	A-14	Fosket Spring	High	BLM Private		1502 1506

[1]For a description of these cells see table 77 for terrestrial (T) ecosystems, table 78 for aquatic (A) ecosystems, and table 79 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate those cells which are considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential components.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of the type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. BLM = Bureau of Land Management, FS = Forest Service, FWS = Fish and Wildlife Service.

[4]See appendix V.

HIGH LAVA PLAINS AND COLUMBIA BASIN PROVINCE, EASTERN OREGON

This province is made up of two distinct areas—that portion of the Columbia Basin which is located in Oregon and the High Lava Plains which occupy much of central Oregon (fig. 1). The High Lava Plains are characterized by young lava flows of moderate relief interrupted by scattered cinder cones and basaltic buttes. As a result of porous bedrock and scanty rainfall, many streams are seasonal. Undrained basins containing playa lakes, some dry and others with fluctuating levels, are common. Most of the area has a base elevation of about 1200 m above sea level.

Geologic formations in the High Lava Plains consist largely of Pliocene and Pleistocene lavas, tuffs, and alluvium. In many areas, Quarternary valley fill deposits overlie the older volcanic flows. These are comprised of alluvium, lake deposits, and eolian sediments, all derived from volcanic rocks of the uplands. The most common soil types are derived from basalt or tuff and commonly have very stony loam textures. In some locations these soils have a silica-cemented hardpan at a depth of approximately one-half m. In the eastern section, Solonetz soils have formed in lacustrine deposits in old lakebeds. These are deep, silty soils with a subsurface horizon of clay and sodium accumulation.

The major portion of the Columbia Basin section in Oregon is underlain by Columbia River basalt of Miocene age. Loess deposits cover the basalt near Moro and in Grass Valley. In addition, a large area near Boardman is mantled by unconsolidated sand of apparently Pleistocene age. For the most part, slopes are moderate with the exception of isolated basaltic buttes or canyons cut by major rivers (e.g., the Deschutes River canyon). Elevations range from about 150 m , adjacent to the Columbia River, to 600 m. Lithosols (shallow, stony, and very poorly developed) and Brown soils are probably the most common soil types in the Oregon Columbia Basin. The Brown soils tend to be minimally developed and are characteristically loam textured.

Steppe and shrub-steppe ecosystems of bunchgrasses and sagebrush cover most of the area (Franklin and Dyrness 1973). In many areas western juniper is present, forming a savanna. Variability in ecosystems is associated mainly with shifts in the composition and structure of the savanna, steppe, and shrub-steppe communities; these shifts are, in large measure, responses to variations in soil characteristics. Some diversity in terrestrial ecosystems is provided by playa and sand dune habitats. Aquatic ecosystems are not abundant and consist mainly of springs, ponds, and marshes; as mentioned earlier many streams are intermittent.

Of the 19 terrestrial cells identified in this province (table 82), 6 provide for representation of western juniper savanna, each representing a distinctive ecosystem, and 5 are for sagebrush-dominated ecosystems ranging from rigid sagebrush on scablands to big sagebrush/bunchgrass types. Grassland ecosystems are identified by four cells, and dune-based ecosystems complete the list.

Springs and a tule marsh make up four of the six aquatic cells identified (table 83). A pond and small stream drainage are also identified as essential cells.

It is assumed that natural areas selected to represent the aquatic and terrestrial cells will include the complement of plant and animal species typical of those ecosystems. Eight vertebrate animal species have been specifically identified as cells because of their rare or endangered status (table 84). Vascular plants of special interest include 12 from the Smithsonian list of endangered or threatened plants (table 85). Over two-thirds of these plants are in the Columbia Basin section of this province.

Two Federal Research Natural Areas and a Nature Conservancy reserve have been established (table 86). Lost Forest, the largest of these, takes in a large dune area and an isolated ponderosa pine forest associated with it. The existing natural areas fill 8 of the 33 cells identified for this province; all of the filled cells are terrestrial.

Nine additional Research Natural Areas should provide minimal coverage of the 25 unfilled cells (table 87). There is considerable question as to whether a single area can be found which includes adequate coverage of three different western juniper types (see need No. 2 in table 87), so two areas may be necessary. No large combined terrestrial and aquatic areas are proposed.

Several State and Federal agencies and private organizations have lead responsibilities (table 87). Oregon State and the Bureau of Land Management are most likely to have suitable lands for most of the terrestrial natural areas, and Fish and Wildlife Service (Malheur National Wildlife Refuge) should have several of the aquatic ecosystems. Priorities are highest for aquatic areas and terrestrial ecosystems subject to heavy grazing or suitable for agricultural use.

Table 82.--*Terrestrial cells in the High Lava Plains and Columbia Basin Province, eastern Oregon*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Ponderosa pine and western juniper communities:			
1. Ponderosa pine/big sagebrush community (isolated stand within steppe)	237	Lost Forest RNA	171-180
2. Ponderosa pine/bitterbrush community (isolated stand within steppe)	237	Lost Forest RNA	171-180
3. Western juniper-ponderosa pine/sagebrush	237 238	Lost Forest RNA	165-167 171-180
4. Western juniper/big sagebrush/threadleaf sedge community	238	Horse Ridge RNA	165-167
* 5. Western juniper/big sagebrush/bluebunch wheatgrass community	238	Horse Ridge and Lost Forest RNA's, but need additional area (may be filled by proposed The Island RNA)	165-167
* 6. Western juniper/Idaho fescue community	238	Token in Lost Forest RNA, additional area is needed	165-167
* 7. Western juniper/bluebunch wheatgrass	238	None	165-167
* 8. Western juniper/big sagebrush-bitterbrush	238	None	165-167
Sagebrush communities:			
* 9. *Artemisia tridentata/Agropyron spicatum* community		None	234-237
*10. *Artemisia tridentata/Festuca idahoensis* community		None	235, 238
*11. *Artemisia arbuscula/Agropyron spicatum* community		None	235, 239-241
*12. *Artemisia arbuscula/Festuca idahoensis* community		None	235, 239-241
*13. *Artemisia rigida/Poa sandbergii* community		None	235, 242
Grassland communities:			
14. *Agropyron spicatum-Poa sandbergii* community		Lawrence Grasslands Memorial Preserve	223
*15. *Eriogonum-Poa sandbergii* scabland		Token in Lawrence Grasslands Memorial Preserve, need additional area	225-227
*16. *Poa sandbergii-Danthonia unispicata* community		None	244-245
17. *Festuca idahoensis-Agropyron spicatum* and associated communities in Columbia Basin		None	244
Special types:			
18. Dunes and shifting sand		Lost Forest RNA	
19. Playas		Lost Forest RNA	

*Cells presently lacking adequate representation.

Table 83.--*Aquatic cells in the High Lava Plains and Columbia Basin Province, eastern Oregon*

Cell[1]	Present representation
*1. Permanent freshwater pond	None
*2. Typical stream drainage at lower elevations	None
*3. Large, upwelling cold spring	None
*4. Cave with cold spring	None
*5. Tule marsh area in the eastern portion of the province	None
*6. Typical hot spring area	None

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 84.--*Rare and endangered vertebrate animal cells in the High Lava Plains and Columbia Basin Province, eastern Oregon*

Cell	Verified representation	Reference
Fish:		
*1. Malheur sculpin	None	Bond 1966
Birds:		
*2. Western burrowing owl	None	Gabrielson and Jewett 1940
Mammals:		
*3. Malheur or Preble shrew	None	Bailey 1936 Olterman and Verts 1972
*4. Merriam shrew	None	Bailey 1936 Johnson and Clanton 1954 Olterman and Verts 1972
*5. Pygmy rabbit	None	Bailey 1936 Olterman and Verts 1972
*6. Pinon mouse (subspecies *preblei*)	None	Bailey 1936
*7. Northern grasshopper mouse	None	Bailey 1936
*8. Sagebrush vole	None	Bailey 1936 Clanton et al. 1971 Johnson et al. 1948 Maser et al. 1974 Maser and Storm 1970 Olterman and Verts 1972

*Cells presently lacking adequate representation.

Table 85.--*Vascular plants of special interest in the High Lava Plains and Columbia Basin Province, eastern Oregon*

Species[1]	Distribution
Allium pleianthum[2]	John Day Valley, Wheeler County
Allium robinsonii	Lower benches of Columbia River
Arenaria franklinii var. *thompsonii*[2]	Sagebrush plains along the Columbia River; Wasco, Gilliam, and Morrow Counties
Artemisia lindleyana	Along Columbia River and tributaries
Astragalus collinus var. *laurentii*	Sandy slopes near Heppner, Morrow County
Astragalus diaphanus	Sandy ground, lower John Day River valley
Astragalus howellii	Sagebrush plains along Columbia River; Wasco, Sherman, Morrow, and Umatilla Counties
Astragalus misellus	Upper forks of Deschutes and John Day Rivers, Wheeler and Grant Counties
Astragalus peckii	Dry sandy ground, west of Tumalo, Deschutes County
Astragalus succumbens	Sagebrush desert, Umatilla and Gilliam Counties
Astragalus tegetarioides	Pine forest, Silvies River, Harney County
Astragalus tyghensis	Tygh Valley, Wasco County
Castilleja xanthotricha[2]	Sagebrush flats, John Day Valley near Clarno
Chaenactis nevii[2]	Dry slopes, John Day Valley
Claytonia umbellata	Rocky ground, Wasco County; also in Steens Mountains
Collomia macrocalyx[2]	Dry open ground near Lone Rock, Gilliam County
Cryptantha leucophaea	Sandy soil along the Columbia River east of The Dalles
Eriogonum cusickii[2]	Rocky, sagebrush area
Lomatium frenchii	Sagebrush, Wasco County near Madras
Lomatium hambleniae	Scablands, Wasco County
Lomatium hendersonii[2]	Dry hills, John Day Valley, Jefferson and Wheeler Counties
Lomatium minus[2]	Scablands, Wasco, Wheeler, and Grant Counties
Lomatium watsonii	Dry hillsides, Wasco and Jefferson Counties
Luina serpentina[2]	Steep serpentine slopes near Dayville, Grant County
Myosurus clavicaulis	Dry watercourses, Silver Creek valley, Harney County
Penstemon eriantherus var. *argillosus*	Dry slopes, Deschutes and John Day River valleys
Penstemon seorsus	Dry stony ridges; Jefferson, Crook, Harney, and Malheur Counties
Pilularia americana	In mud of vernal pools, Crook County to California
Potentilla glandulosa var. *campanulata*	John Day River valley near Dayville
Ranunculus reconditus[2]	Sagebrush slopes, Wasco County
Silene scaposa var. *scaposa*[2]	Gilliam and Wheeler Counties to Blue Mountains
Sisyrinchium douglasii	White color form found near Maupin, Wasco County
Stephanomeria malheurensis[2]	Sagebrush, Narrows, Harney County
Talinum spinescens	Scablands, Wasco County

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]Species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 86.--*Established Research Natural Areas in the High Lava Plains and Columbia Basin Province, eastern Oregon*

Name	Principal features	Agency[1]	Area Ha	Area Acres
Horse Ridge RNA	Western juniper savanna	BLM	243	600
Lawrence Grasslands Memorial Preserve	Bluegrass-bunchgrass Community on biscuit scabland near Shaniko, Oregon	TNC	153	378
Lost Forest RNA	Isolated ponderosa pine stands and sand dunes within a low rainfall, shrub-steppe region in central Oregon	BLM	3 628	8,960

[1]BLM = Bureau of Land Management, TNC = The Nature Conservancy.

Table 87.--*Additional Research Natural Areas needed in the High Lava Plains and Columbia Basin Province, eastern Oregon*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Predominantly terrestrial natural areas:						
1. A variety of big sagebrush and low sagebrush communities	T-9,10,11, 12,5,6,7 R&E-2,4,5, 6,7	Squaw Butte Experimental Range is a possible candidate	High	State FWS BLM	234-242	1300
2. Western juniper/big sagebrush/ bluebunch wheatgrass, western juniper/ bluebunch wheatgrass, and western juniper/big sagebrush-bitterbrush communities	T-2,5,7,8, 6,15	Pine Ridge, Gray Buttes, Juniper Butte. (The Island RNA(proposed) will also partially fill this need.)	Low	BLM State FS	165-167	1303
3. Scabland with stiff sagebrush-*Poa* and *Eriogonum-Poa* communities	T-13,15,16		Medium	BLM Private	225-227 242, 245	1109
4. Idaho fescue-bluebunch wheatgrass associated communities in Columbia Basin area	T-17		High	State Private	244	
Predominantly aquatic natural areas:						
5. Typical stream drainage at low elevations	A-2	May not be available	Medium	BLM Private		
6. Large, upwelling cold spring	A-3 R&E-3	Stinking Lake, Malheur National Wildlife Refuge	High	FWS		
7. Cave with cold spring	A-4	Malheur Cave	High	Private		1300
8. Hot spring	A-6	00 Ranch (Malheur National Wildlife Refuge)	High	FWS		1300
9. Tule marsh with permanent ponds	A-1,5 R&E-3	Malheur National Wildlife Refuge	High	FWS		1300

[1]For a description of these cells see table 82 for terrestrial (T) ecosystems, table 83 for aquatic (A) ecosystems, and table 84 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate cells considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of that type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. BLM = Bureau of Land Management, FWS = Fish and Wildlife Service.

[4]See appendix V.

VYHEE UPLAND PROVINCE,
)UTHEASTERN OREGON

The Owyhee Upland Province is, for the most part, a gently sloping north-facing basin which is drained by the Owyhee River (fig. 1). Steep slopes are largely restricted to areas adjacent to the river, especially as it approaches its confluence with the Snake River. Much of the area is a high, gently rolling plateau with a base elevation of approximately 1200 m.

The most common geologic formations are Miocene and Pliocene beds of tuffaceous sedimentary rocks capped by flows of rhyolite and basalt. In addition, thick beds of quartzose sandstone, siltstone, and conglomerate outcrop near the mouth of the Owyhee River. The most recent volcanic activity in the area occurred during the Pleistocene and resulted in basalt flows of limited extent at Diamond and Cow Lake Craters.

Soils in the Owyhee Upland Province fall largely into the Sierozem and Brown great soil groups and reflect the effects of low amounts of precipitation. On basaltic parent materials, these soils have a very stony loam surface horizon underlain by either a clay or stony loam subsoil which may include a silica-cemented hardpan.

Sagebrush/bunchgrass communities dominate the Owyhee Uplands (Franklin and Dyrness 1973). In some upland areas, western juniper or mountain mahogany join with shrub and grass species in savanna ecosystems. In low-lying areas, often associated with vernal pools or playas, are communities with *Artemisia cana, Elymus cinereus,* or *Atriplex*. Areas of recent vulcanism and the Owyhee River canyon and associated tributaries are sites providing additional ecosystem and species diversity. Small permanent and vernal ponds of varying chemistry are the most common aquatic communities.

Research Natural Areas established to fill terrestrial (table 88) and aquatic (table 89) cells should include the typical array of plant and animal species. Six vertebrate animals are identified as species which should receive specific attention because of their rare or endangered status (table 90). Seventeen vascular plant species are known to be of special interest, and 10 of these are on the Smithsonian list of endangered or threatened plants (table 91). The majority of the latter plants are located in or near the Owyhee River canyon.

A minimum of eight Research Natural Areas should provide for representation of identified terrestrial, aquatic, and animal cells (table 92). None exist at present, although Jordan Craters is an area under consideration for Research Natural Area establishment. Lead responsibility in this province appears to lie almost entirely with the Bureau of Land Management.

Table 88.--*Terrestrial cells for the Owyhee Upland Province, southeastern Oregon*

Cell	SAF timber type No.	Present representation	Page reference (Franklin and Dyrness 1973)
Western juniper communities:			
* 1. Western juniper/big sagebrush/bluebunch wheatgrass community	238	None	165-167
* 2. Western juniper/Idaho fescue community	238	None	165-167
* 3. Western juniper/bluebunch wheatgrass community	238	None	165-167
Sagebrush communities:			
* 4. *Artemisia tridentata/Agropyron spicatum* community		None	235-237
* 5. *Artemisia tridentata/Festuca idahoensis* community		None	235, 238
* 6. *Artemisia arbuscula/Agropyron spicatum* community		None	235 239-241
* 7. *Artemisia arbuscula/Festuca idahoensis* community		None	235 239-241
* 8. *Artemisia arbuscula/Danthonia unispicata/ Koeleria cristata* communities		None	239-241
* 9. *Artemisia tridentata/Elymus cinereus* community		None	235, 239
*10. *Artemisia rigida/Poa sandbergii* community		None	237
*11. *Artemisia cana* community		None	242-243
Other ecosystems:			
*12. Mountain mahogany savanna		None	243-244
*13. *Elymus cinereus* community		None	246
*14. *Atriplex confertifolia-Grayia spinosa* community		None	245
*15. Lava flow area		None	34-35

*Cells presently lacking adequate representation.

Table 89.--*Aquatic cells for the Owyhee Upland Province, southeastern Oregon*

Cell[1]	Present representation	Remarks
*1. Lowland lake	None	Proposed Jordan Craters RNA would fill need
*2. Permanent pond	None	Proposed Jordan Craters RNA would fill need
*3. Vernal ponds	None	Proposed Jordan Craters RNA would fill need
*4. Swamp	None	Proposed Jordan Craters RNA would fill need
*5. Marsh	None	Proposed Jordan Craters RNA would fill need
*6. Stream	None	
*7. Springs	None	
*8. Alkali vernal ponds	None	Coyote Lake (playa)

[1]Each aquatic cell identified is assumed to include the functional groups of organisms and dominant species which typify the listed ecosystem.

*Cells presently lacking adequate representation.

Table 90.--*Rare and endangered vertebrate animal cells in the Owyhee Upland Province, southeastern Oregon*

Cell	Verified representation	Reference
Mammals:		
*1. Merriam shrew	None	Bailey 1936 Johnson and Clanton 1954 Olterman and Verts 1972
*2. White-tailed jack rabbit	None	Bailey 1936 Olterman and Verts 1972
*3. Richardson ground squirrel	None	Bailey 1936 Olterman and Verts 1972
*4. Little pocket mouse	None	Bailey 1936 Olterman and Verts 1972
* 5. Northern grasshopper mouse	None	Bailey 1936
*6. Sagebrush vole	None	Bailey 1936 Clanton et al. 1971 Johnson et al. 1948 Maser et al. 1974 Maser and Storm 1970 Olterman and Verts 1972

*Cells presently lacking adequate representation.

Table 91.--*Vascular plants of special interest in the Owyhee Upland Province, southeastern Oregon*

Species[1]	Distribution
Astragalus iodanthus var. *vipereus*	Bluffs, eastern Malheur County
Astragalus mulfordae[2]	Dry sandy ground, lower Owyhee River, eastern Malheur County
Astragalus nudisiliquus	Gravelly bluffs, northeastern Malheur County
Astragalus purshii var. *ophiogenes*[2]	Sagebrush desert, Owyhee River, Malheur County
Astragalus solitarius[2]	Usually in sagebrush, Owyhee River, Malheur County
Astragalus sterilis[2]	Clay hills, Sucker Creek, Malheur County
Cryptantha propria	Dry hillsides, northern Malheur County
Cymopterus corrugatus[2]	Dry hills, southern Malheur County
Eriogonum novonudum[2]	Stony clay hills, eastern Malheur County
Eriogonum ochrocephalum ssp. *calcareum*	In loose, white volcanic ash, Malheur County
Hackelia cronquistii[2]	
Hackelia ophiobia[2]	Cliffs, 3 forks of Owhyee River, Malheur County
Hackelia patens	Between Vale and Harper, Malheur County
Mentzelia mollis[2]	Clay slopes, eastern Malheur County
Mirabilis bigelovii	Canyon of Owyhee River, Malheur County
Silene scaposa var. *lobata*[2]	
Trifolium owyheense	Dry slopes, Sucker Creek, Malheur County

[1]These plants are tentatively identified as deserving special consideration in land management activities, including selection of Research Natural Areas. Reasons for listing include known or probable rare or endemic status, disjunct populations, or identification nationally (in the Smithsonian Institution list) as threatened or endangered species.

[2]Species is on the national list of threatened and endangered plants (Smithsonian Institution 1974).

Table 92.--*Research Natural Areas needed in the Owyhee Upland Province, southeastern Oregon*

Ecosystem or community	Cells represented[1]	Remarks and possible locations	Priority[2]	Lead agency[3]	Page reference (Franklin and Dyrness 1973)	Sub-province[4]
Combined terrestrial and aquatic areas:						
1. Area with lake, ponds, and marshes, recent lava flows, and some surrounding upland	T-9,13,15 A-1,2,3, 4,5	Proposed Jordan Craters RNA will fill this need	High	BLM	34-35	1507
2. Alkali vernal ponds and *Artemisia cana* communities	T-11 A-8	Coyote Lake	High	BLM	242-243	1502
Predominantly terrestrial areas:						
3. Area with variety of big and low sagebrush communities	T-4,5,6,7 R&E-1,2,3, 4,5,6	Sucker Creek area; consider plants of special interest	Low	BLM State	234-242	1507
4. Juniper and sagebrush communities	T-1,2,3, 8,10 R&E-1,2,3, 4,5,6		High	BLM State	165-167	1504 1507
5. Mountainmahogany savanna	T-12		Medium	BLM	243-244	1505
6. Shadscale and winterfat communities	T-14		High	BLM	245	1507
Predominantly aquatic areas:						
7. Springs and stream	A-6,7		High	BLM		1504 1507
Areas for plants of special interest:						
8. Concentration of rare and endangered plants along Owyhee River		See table 91	Medium	BLM		1504

[1]For a description of these cells see table 88 for terrestrial (T) ecosystems, table 89 for aquatic (A) ecosystems, and table 90 for rare and endangered (R&E) vertebrate animals. Underlined cell numbers indicate cells considered essential components of the proposed Research Natural Area. Those not underlined represent cells which would be desirable but not essential.

[2]Based mainly upon how endangered areas of that type are believed to be, not how extensive the type is, i.e., the danger that all examples of that type will be lost to other uses. Acquisition urgency.

[3]Agency or institution most likely to have or to be able to acquire a tract of the desired type based on land ownership. BLM = Bureau of Land Management.

[4]See appendix V.

Part III. Marine and Estuarine Research Natural Area Needs

Developing an approach to selection of a series of marine and estuarine Research Natural Areas turned out to be difficult in this biologically and legally complex coastal region.

The objective was to outline the type and number of natural areas needed to preserve examples of the varied types of coastal and near-shore ecosystems found along the Oregon and Washington coasts. The initial approach was to break down the coastline into districts or provinces (open coasts of the two States and northern and southern segments of Puget Sound) and subdivide each district into major habitats—estuaries and related types, exposed intertidal and subtidal strand on open coast, cliffs and rocks, and subtidal communities as well as unique ecosystems or organisms. This was an obvious attempt to develop a cellular matrix as was followed in developing natural area needs for inland waters.

In fact, developing a cellular matrix proved very difficult. The working group was small and did not have sufficient knowledge of all areas. Many marine and estuarine ecosystems are unique. Furthermore, any plan must recognize the limitations imposed by present human developments, i.e., relatively few potential sites are suitable as sites for Research Natural Areas. Nevertheless, a list of natural area needs was developed in the framework of the provinces and habitat subdivisions outlined above. Many of the listed needs identified specific areas for exemplary purposes rather than cells in the sense of the other working groups.

The initial list was subjected to an extensive review process and received considerable, constructive criticism from experts in the area of coastal and estuarine ecosystems. As a consequence, an additional meeting of the working group was held in November 1974 to develop a revised listing of Research Natural Area needs.[3]

The objective in the listings which follow is to identify a series of areas which in their totality encompass the important variations in habitats, communities, and organisms. The areas listed include some which are essential because they are the last remaining example, are unique biologically, or have an established history of research. Some of the other areas are listed as examples of particular kinds of habitats, and better sites as Research Natural Areas might exist.

The geographic subdivisions used in the listings are:

a. Open coast of Oregon,
b. Open coast of Washington,
c. Puget Sound,
d. Straits of Georgia and Rosario Straits,
e. Waters of San Juan archipelago.

The Puget Sound subdivision includes those water bodies entered by way of Admiralty Inlet and Deception Pass, including the Hood Canal. The waters to the north and west of these inlets to the Canadian border constitute the region known as the Straits of Georgia and Rosario Straits. The waters around the San Juan archipelago and Cypress Island are recognized as a special unit because of their distinctive biology and the long history of research by the Friday Harbor Laboratories of the University of Washington; they also have unique legal status as a marine biological preserve under a Washington State law.

The habitat subdivisions, under which specific sites are generally categorized, are divided in two ways—estuarine and open coast areas. Natural areas in *estuaries* should be chosen to represent the range in estuary size from small to large, and range in salinity characteristics from low to high. By this crude two-dimensional initial breakdown, the possibility of including the full spectrum of estuary conditions within a system of Research Natural Areas will be greatly enhanced. Tidal flushing, sediment flow, dissolved minerals, and seasonal and lunar cycles of salinity will vary with the size of the estuary and the volume of fresh water pouring into it. Smaller estuaries are much more likely to be in a nearly undisturbed state; most are not influenced by urban wastes; and they generally have not been dredged. Smaller estuaries would be expected to have still waters, and larger ones generally have considerably more wave action.

We do not envision setting aside entire large estuaries as Research Natural Areas; natural areas in this situation should consist of relatively undisturbed arms or portions of the entire embayment or slough. However, it is our expectation that areas designated within large sloughs will, in some cases, extend from high marsh and swamp (for example, *Picea* forest) through the intertidal to the subtidal, and that in the subtidal different bottom sediments will be represented.

In the case of small estuaries, it may be possible to find examples with unmanaged, natural mouths where hydrologic processes are naturally played out. In these instances, the entire estuary and its margin should be placed in natural area status. A significant factor in selection may be the presence of sometimes submerged sandbars that drastically alter community structure.

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[3] Many people have contributed to this effort besides the original working group. Special gratitude is due Robert L. Fernald (University of Washington); Austin Pritchard, Vicki Osis, and Chris Bayne (Oregon State University); Laimons Osis (Oregon Fish Commission); and R. L. Bacon (University of Oregon). These individuals attended the meeting in November 1974 at which the revised lists were developed. Robert Fernald and Austin Pritchard made outstanding contributions in the revision of the lists for Washington and Oregon, respectively. Other valuable suggestions were offered by Jefferson J. Gonor, Robert Waaland, Richard Norris, Thomas Mumford, Peter B. Taylor, Peter W. Frank, Paul P. Rudy, and Robert T. Paine.

Along *exposed shorelines*, variables of temperature, salinity, wave action, depth, slope gradient, and substrate present a variety of habitats with associated communities. In these situations we envision linear natural areas which extend perpendicularly to the shore from above the splash zone out into the subtidal. Each area should include approximately one-fourth to 1 mile of shoreline. The series of Research Natural Areas should include intertidal habitats on a wide variety of substrate types—ranging from sandstone to serpentine in mineralogy and from coherent rock to sands and gravels. Selection of rocky sites should include consideration of a variety of tidal pools, surge channels, and rock configurations, as well as the chemical makeup of the rock.

Ocean-front cliffs and *offshore islands* often comprise important rookeries for both birds and mammals. For this reason, many of these areas are already protected from disturbance by such agencies as the U.S. Department of Interior, Fish and Wildlife Service. However, we feel that at least a small number of the most typical of these areas should also be designated as Research Natural Areas. In most cases areas so designated should also include the adjacent intertidal zone which, for example, may be influenced by excrement. We would also recommend the inclusion of bluffs present on some of the larger islands in Puget Sound and the outer coast as well. The distinctive nesting sites of burrowing and cliff- and slope-nesting birds should be taken into account. In addition, several rookeries and hauling-out areas of seals and sea lions should be given natural area status.

Finally, there is a need for at least two extensive areas that include not only a fringe of shore but also a generous portion of a coastal terrestrial ecosystem. These will provide areas for the study of interconnections between marine and terrestrial systems, especially of mammals and birds which utilize both types of environments. Mink, otters, raccoons, and bald eagles are examples of such animals. Possibly these large combined natural areas could be established in conjunction with estuarine or exposed coast ecosystems.

Research Natural Area needs are identified in tables 93-98. These total 68. We again caution the reader that this is a first approximation. We have tried to include examples of the major coastal and estuarine habitats, ecosystems, and organisms, as well as to identify unique sites which must be preserved. Future revision will be essential, but it is hoped that this list will assist land planners in coastal areas in identifying areas critical for research and preservation of exemplary organisms and ecosystems.

Table 93.--*Areas suggested for Research Natural Areas representative of estuarine ecosystems on the coast of Oregon*

Estuary	Comments and priority
Sand Island and Baker Bay near the mouth of Columbia River estuary	A large, high-salinity area of high to intermediate priority.
Nehalem River estuary, specifically Lazarus Island, Dean Point, and adjoining tidelands	A low-salinity area in a small, low-salinity estuary. Intermediate priority.
Tillamook Bay	A large estuary with variable salinity. An undisturbed arm of the bay required, assuming one exists. Low priority.
Netarts Bay and sand spit	A small, high-salinity estuary that is relatively undisturbed. Portion of the estuary and salt marsh required. High priority. Cape Lookout State Park adjoins salt marsh and controls sand spit.
Nestucca River estuary and sand spit, including confluence with Little Nestucca River	A small, low-salinity estuary that is relatively undisturbed. High priority.
Salmon River estuary	A small, high-salinity area at the mouth. Some distinctive animal communities. Adjoins Nature Conservancy land and is in newly designated "Scenic Research Area." High priority.
Siletz estuary, specifically the rocky intertidal area where Schooner Creek enters	Very limited area which is habitat for the only stable population of *Littorina sitkana* in Oregon. Low priority.
Yaquina Bay, specifically:	
a. Idaho Flat tideflat	A high-salinity area in a large estuary of varied salinity. High priority. Area deeded to Oregon State University by Georgia-Pacific Corporation.
b. McCaffery and Poole Sloughs	A relatively undisturbed, low-salinity area of high priority.
c. Boone and Nute Sloughs	A low-salinity area that is an old river oxbow. This area has been blocked off from tidal action by road fill and tide gates but proposed road alinement presents an opportunity to install adequate culverts to restore marsh areas. Low to intermediate priority.

Table 93.--*Areas suggested for Research Natural Areas representative of estuarine ecosystems on the coast of Oregon* (Continued)

Estuary	Comments and priority
Alsea Bay, specifically:	
a. Barview mudflat area	A large, relatively undisturbed mudflat in a large, low-salinity estuary. High priority.
b. Area where Drift Creek enters Alsea River estuary	Area about 5 miles from mouth of estuary, low salinity, high priority. Relatively undisturbed. Extensively studied in upper reaches of Drift Creek by Oregon Wildlife Commission and Oregon State University.
Siuslaw River estuary, specifically Cox Island and surrounding areas	Relatively undisturbed island and tideflats in a small, low-salinity estuary. High to intermediate priority.
Umpqua River estuary	Large, low-salinity estuary. Low priority.
Coos Bay, specifically:	
a. South Slough	High-salinity slough in a large estuary with varied salinities. High priority. The area is being processed as an estuarine sanctuary.
b. Additional areas in main estuary and North Slough	Variable salinity. High priority. May be difficult to find areas not encroached by road fills and urbanization pressures.
Coquille River estuary, specifically tidelands and marshes between Bullards Beach State Park and Bandon	Low-salinity, relatively undisturbed area in a small, low-salinity estuary. Intermediate priority.

Table 94.--*Areas suggested for Research Natural Areas representative of intertidal ecosystems on the open coast of Oregon*

Area	Comments and priority
Ecola Point and adjacent sandy beaches	Part of Ecola State Park; high priority. Headland and beach communities typical of the northern Oregon coast.
Sandy beach between Seal Rock and Beaver Creek (Lincoln County)	Area typical of the central coast. Intermediate priority.
Neptune State Park including Strawberry Hill area	High priority. A mixture of basaltic bedrock shelves, tide channels and pools, and gravel and sandy beaches on central Oregon coast. Strawberry Hill area contains relatively large numbers of certain invertebrates (nudibranchs, large tube worms) not common in other Oregon outer coast intertidal areas.
North Cove of Cape Arago including Shell Island and adjacent reefs	A varied invertebrate community and diverse habitat. Several species reach their northern limits here. High priority.
Cape Blanco	A relatively isolated headland on southern Oregon coast. Adjoins a recently developed State Park. High priority.
Brookings area-Harris Beach State Park	Between 42° 1' and 40° 2' is an excellent area for marine algae of a great variety. Extensively studied by Doty and Norris. High priority.
Section of sand beach between Florence and Coos Bay	Representative sand beach area along the dune sheet. High priority.
Sandy beach of Clatsop Plains of northern Oregon	Good sand beach area representative of the northern Oregon coast region. High priority.
Rocky shores in Port Orford area, possibly around closed U.S. Coast Guard Station	Rocky shore habitats representative of the southern Oregon open coast. Area near Port Orford is used by Oregon State University biologists. High priority.
Boiler Bay	Field of boulders that is exposed to the northwest and protected from the southwest by high reefs. Good for both marine plants and animals. Unusually rich in biota and habitat diversity. High priority.
Yaquina Head near Newport Marine Laboratory	For fauna and flora one of the most important headlands in Oregon. Tip is already Federal property and a sea bird and mammal sanctuary. High priority.
"Marine gardens" area at Otter Rock	Excellent area where collecting has been prohibited for at least a decade. Access is limited. Intertidal bench of sandstone and basalt dikes with northern exposure. High priority.
Whale Cove	Undisturbed pocket cove which has been protected from collecting; diverse fauna and flora. Intermediate priority.

Table 95.--*Areas suggested for Research Natural Areas representative of exposed intertidal ecosystems on the open coast of Washington including Straits of Juan de Fuca*[1]

Area	Comments and priority
Copalis Beach	Open sandy beach and razor clam populations. Area has received considerable attention in diatom productivity studies dating from 1930. High priority.
Destruction Island off the coast of Washington near Ruby Beach	Isolated, highly exposed small island. Wildlife sanctuary and site of marine bird population studies.
Cape Alava and Flattery Rocks	Exposed rocky shoreline associated with extensive sandy beaches. Natural protection by removal from roads and easy access. Diverse fauna and flora. Part of Olympic National Park shores. High priority.
Point of the Arches and offshore islets	Exposed rocky shores and sandy beaches. Diversity of habitats accessible by trail.
Shi Shi Reef and beach area with Portage Head	Complex of exposed rocky intertidal region with sandy and gravelly beaches. Base for studies in marine ecology and population biology. Protected by limited accessibility. High priority.
Tatoosh Island	Offshore island near Cape Flattery with diverse habitats having varying exposure to tidal influences. Excellent for faunistic and floristic studies requiring high degree of protection from human intrusion. High priority.
Waada Island	Offers areas with high degree of exposure and protection. Diversity of flora and fauna. High priority.
Slip Point on Clallam Bay	Excellent populations of *Strongylocentrotus purpuratus* and associated exposed intertidal fauna and flora. On property controlled by the U.S. Coast Guard. High priority.
Pillar Point	Predominantly rocky intertidal region of moderate exposure.
Tongue Point and Crescent Beach, Clallam County Park	Rocky intertidal region of moderate exposure and associated mud-sand beach. Good populations of three species of sea urchins and associated flora and fauna. Good semi-protected beach habitat. High priority.
Dungeness Spit	Exposed sandy gravel beach with typical flora and fauna. Diverse beach dwelling polychaetes, bivalves, crustaceans, etc. High priority.
Protection Island, Jefferson County, at entrance to Discovery Bay near Port Townsend	The Nature Conservancy has purchased 48 acres at the west end of island as a preserve for a nesting colony of rhinoceros auklets. Harlequin ducks, seals, scoters, etc., also inhabit its shores. Interesting intertidal areas. High priority.

[1]Series of areas are suggested along the straits which offer varying degrees of exposure.

Table 96.--*Areas suggested for Research Natural Areas representative of estuarine ecosystems on the open coast of Washington*

Estuary	Comments and priority
Portion of Willapa Bay including Leadbetter Point	Excellent protected bay with sand and mud substrate. Bivalves (including oysters), crabs, etc., with good population of an enteropneust, *Saccoglossus* sp. Introduced population of *Ilyanassa obsoleta*. High priority.
Marshlands at Campbell Slough and Oyhut in North Bay of Grays Harbor	Protected estuarine area with limited marshlands associated with mud-sand flats. High priority.
Queets River estuary	Relatively small estuary representative of central coast of Washington.

Table 97.--*Areas suggested for Research Natural Areas representative of estuarine ecosystems in Puget Sound and in the Straits of Georgia and Rosario Straits*

Estuary	Comments and priority
Burn's Point and cove on Totten Inlet, lower Puget Sound	Representative of the lower Puget Sound estuarine areas. High priority.
Steamboat Island at mouth of Totten Inlet	An area representing both gravelly and boulder shores. High priority.
Nisqually River delta	Diverse habitats including marsh areas in one of the largest undeveloped estuarine areas in Puget Sound. Recently acquired by the Fish and Wildlife Service. High priority.
The Narrows-Tacoma, southwest from Salmon Bay	Rocky fill with rapid tidal currents. Artificially developed area of high diversity in fauna and flora. Excellent for many invertebrate forms including *Octopus dofleini*. High priority.
Quartermaster Harbor on Vashon Island	Good mud bay with representative populations of bivalves, crabs, etc.
Double Bluff, on Whidbey Island between Mutiny and Useless Bays	Sandy beaches with some rocky outcrops.
Skagit Flats and Goat Island	Excellent and extensive mudflats with rocky island shores and associated marshes. Large populations of resident and migratory marine birds, etc. High priority.
Sister's Point at Great Bend of Hood Canal	Selected as area representative of the lower Hood Canal region. Mud-shell substrate. High priority.
A portion of Dabob Bay	Associated with upper Hood Canal. Mud substrate and associated fauna. High priority.
Big Beef Creek (east side of Hood Canal)	Stream contains established runs of chum and coho salmon and steelhead trout. Area owned by University of Washington, College of Fisheries. High priority.
Foulweather Bluff	Exposed rocky shores at entrance to Hood Canal. Excellent for diversity of flora and fauna. High priority.
Padilla Bay and Saddlebag Island[1]	Large mud bay between mainland and northern end of Fidalgo Island. Island is small and State-owned.
Nooksack River delta and part of Lummi Bay[1]	North branch of Nooksack entering Lummi Bay is part of Lummi Indian Reservation but is representative of northernmost estuary in Whatcom County. High priority.
Cobblestone beach, Sandy Point to Point Whitehorn (portion of)	Excellent in spite of several oil refineries in area. High priority.

[1]Areas associated with Straits of Georgia and Rosario Straits.

Table 98.--*Areas suggested as Research Natural Areas representative of exposed intertidal ecosystems in waters of the San Juan archipelago and at the confluence of Rosario Straits and Straits of Georgia*

Area[1]	Comments and priority
Fidalgo Head including Shannon Point - RGS	Diverse rocky intertidal region. High priority.
Clayton Beach off Samish Bay near Larrabee State Park - RGS	The only real sandy beach in this region. Excellent example of sand fauna, etc. High priority.
Marine park area between south Bellingham and Post Point - RGS	Cobblestone and rocks with shelving mud and sand at lower depths.
Chuckanut Island and rock in Chuckanut Bay - RGS	Excellent small areas for rocky intertidal and subtidal fauna and flora. Rock controlled by Bureau of Land Management. High priority.
Lummi Rocks off Lummi Island - RGS	Small rocky intertidal and subtidal area. Excellent for representative forms. Controlled by Bureau of Land Management. High priority.
Partridge Point and Partridge Bank on Whidbey Island - S&J	Area of considerable interest for diverse marine flora. High priority.
Smith Island - S&J	Highly diverse intertidal and benthic areas. Excellent for both marine invertebrates and algae. Rock, sand, and gravel with varying exposure to tidal currents. Enjoys excellent protection from general public. High priority.
Deception Pass and Deception Island - S&J	Unique area with exposure to varying currents and tides.
San Juan archipelago and Cypress Island - SJA	This highly diverse, rich area has been a Marine Biological Preserve by State of Washington law since 1923. The area has been intensively used as a base for scientific research for over 70 years. Optimally it would be desirable to implement and extend the provisions of the law. It would be important to provide some protection from commercial exploitation of edible invertebrates in the region. High priority.

[1]RGS = confluence of Rosario Straits and Straits of Georgia; S&J = confluence of Straits of Juan de Fuca and waters of the San Juan archipelago; and SJA = waters of San Juan archipelago, also known as Washington Sound or a part of Straits of Georgia.

Part IV. Reports of Working Groups

REPORT OF TERRESTRIAL WORKING GROUPS

Two terrestrial working groups were organized at the workshop—one group for provinces west of the Cascade crest (West-side Terrestrial Working Group), and the other for provinces in eastern Oregon and Washington (East-side Terrestrial Working Group). The participants in these working groups are listed in appendix VII.

The groups were charged with the responsibility of identifying those terrestrial ecosystems in Oregon and Washington which should have adequate representation in a well-rounded system of Research Natural Areas. Before the workshop, preliminary lists of terrestrial natural area needs had been developed for each province by Jerry F. Franklin and Curt Wiberg. The working groups used these lists as a point of departure. The general procedure was to go through these lists area by area, evaluating each in turn, and making such revisions as necessary.

Our ultimate aim was to construct a list of terrestrial ecosystem cells which should ideally be well represented in a minimal natural area system. Our working definition of a cell—community, organism, or habitat to be represented within a Research Natural Area—has already been more fully covered in part I of this report. In dealing with terrestrial ecosystems, a cell may be a timber type ("mixed-conifer forest with western larch dominance"), a plant community ("Douglas-fir/swordfern"), or a specialized habitat ("shifting dunes"). In some instances, we also used cells to designate geographic location. For example, in the Oregon Coast Ranges Province two western hemlock/swordfern community cells are listed—one in the northern portion of the province and one in the southern. This was judged necessary in order to provide an adequate sample of the diversity which exists in this very widely distributed forest community.

In order to insure as complete coverage as possible, we attempted to include, at a minimum, virtually all major vegetation types described in *Natural Vegetation of Oregon and Washington* (Franklin and Dyrness 1973). In eastern Washington the vegetation classification is based almost entirely on the work of Daubenmire and Daubenmire (1968) and Daubenmire (1970).

The total number of terrestrial cells, both filled and unfilled, is shown by province in table 99. The unfilled terrestrial cells (i.e., those not adequately represented in already established Research Natural Areas) were first arranged into combinations which could be expected to occur in the field, then interfaced with aquatic and rare and endangered animal cells, to finally produce the lists of Research Natural Area needs which appear in part II.

Table 99.--*Number of filled and unfilled terrestrial cells, by State and and province*

Province	Number of filled cells	Number of unfilled cells	Total
Washington:			
Olympic Peninsula and Southwestern Washington	8	19	27
Puget Trough	2	14	16
Western Slopes and Crest, Washington Cascades	16	15	31
Eastern Slopes Washington Cascades	4	17	21
Columbia Basin, Washington	7	36	43
Okanogan Highlands	5	22	27
Total	42	123	165
Oregon:			
Oregon Coast Ranges	5	18	23
Western Oregon Interior Valleys	8	18	26
Siskiyou Mountains	7	19	26
Western Slopes and Crest, Oregon Cascades	7	20	27
Eastern Slopes Oregon Cascades	9	8	17
Ochoco, Blue, and Wallowa Mountains	6	19	25
Basin and Range	0	19	19
High Lava Plains and Columbia Basin, Oregon	8	11	19
Owyhee Upland	0	15	15
Total	50	147	197
TOTAL	92	270	362

REPORT OF AQUATIC (FRESHWATER) WORKING GROUP

We believe that the same rationale under which terrestrial areas have been protected in Research Natural Areas applies also to aquatic areas; i.e., benchmark areas, centers for research activity, and gene pools. Accordingly, we have devised a scheme that we think includes most of the needed Research Natural Areas in Oregon and Washington. We have attempted to include all types of aquatic habitat, concentrating on typical areas and representative faunas, but also considering unique habitats. The urgency of this effort is underscored by the fact that some natural aquatic habitats that should be in the system are simply no longer available, due to man's activities.

We encountered two basic problems in setting up our classification scheme—(1) uncertainty as to how fine a classification to employ, and (2) concern over the difficulty of maintaining aquatic areas in a "natural" state.

There is no commonly accepted classification scheme for aquatic habitats analogous to the plant community types that form the basis for terrestrial Research Natural Areas. For the tentative listing, we have selected a classification that is essentially geographical, emphasizing elevation range within physiographic provinces. Within that framework we have made some further subdivisions, but some important types may have been overlooked. For example, geologic and hydrologic criteria should be added.

A major problem in the establishment of aquatic Research Natural Areas is the extent to which aquatic systems are affected by man's activity on the watershed. It is possible to designate a terrestrial area of 100 acres in many locations and provide for its complete protection from man-caused change. Unless the entire drainage area of a lake, or the watershed area above a stream section, is maintained, however, there is no assurance of protection for aquatic areas. This is particularly true in watersheds subject to logging, but other disturbances can also be important, e.g., pesticide application. The influence is more likely to be of concern in streams than lakes; and it is possible that we might establish certain lakes as Research Natural Areas without including the entire drainage basin, depending on the size and runoff characteristics of the basin. Our present recommendation is that streams not be included unless the entire watershed can be included within the boundaries of the Research Natural Area.

This, of course, limits the size of stream that can be included. Large streams and rivers will be excluded by this criterion. We do feel that a need exists to identify research areas in such waters, but suggest that some classification other than Research Natural Area be employed (perhaps incorporating the Wild and Scenic Rivers Act, for example).

We have, thus, tentatively recommended inclusion of only those areas that can most likely be protected from man's influence. However, this decision should be subject to further discussion. For one thing, even the terrestrial areas are not entirely immune from outside influence (consider the ubiquitous nature of DDT, for example). The distinction we have made may be only one of degree, and we perhaps should consider whether classification of such large streams and rivers might provide additional incentive for maintaining them in as close to natural condition as possible.

The basic classification scheme shown in tables 100 and 101 draws considerably on the preliminary work of Franklin and Wiberg. We have made the following basic classification of aquatic habitats: lake, permanent pond (less than 5 acres, shallow, rooted vegetation throughout), vernal pond (temporary), stream, springs (hot and cold), swamp, marsh, and bog. On this classification we have imposed a matrix of elevation and physiographic province. In general, we have included only one representative cell in each square, hoping that this will fulfill the objective. In several instances, when we were aware of significant variation within a square, we included more than one cell. Our limited familiarity with some regions of Oregon and Washington has undoubtedly resulted in some omissions.

We were uncertain as to how to explicitly handle many factors that we recognize as important in the establishment of aquatic Research Natural Areas. For example, in stream classification, gradient and total dissolved solids are important variables affecting productivity. Likewise with lakes, temperature regime, nutrient level, geological origin, and other factors are important. Our present decision is simply to list these variables (and others that may be recommended) as among those criteria that should be considered in the total system. Efforts should be made to incorporate gradients of these elements within each aquatic class over the Pacific Northwest. We believe, in fact, that the system as set up will naturally provide for many of these gradients—for example, a range from oligotrophy to eutrophy in lakes and ponds.

We are still uncertain as to how some manmade bodies of water should be handled. In the Columbia Basin of Washington, for example, are a series of potholes and wasteways. These are the result of irrigation flooding and are more or less permanent bodies. However, they cannot be controlled in the sense of maintaining "natural" conditions, so perhaps should fall into the same category as large river segments. Another problem comes from impoundments, which are common in eastern Washington and Oregon. Although man made, they are usually subject to more control and perhaps should be considered for Research Natural Area status. They are not listed in our present structure.

Tables 100 and 101 show how aquatic cells were selected for the 15 provinces in Oregon and Washington. At present, only 18 aquatic cells are filled out of a total of 180 cells (table 102). It is apparent that much work remains to be done in setting aside typical aquatic ecosystems for research and educational purposes.

The concept of aquatic Research Natural Areas is a new one. Suggestions for improvement in the classification scheme and identification of areas that have been omitted are sincerely solicited.

Table 100.--*Selection criteria of aquatic cells for the six physiographic provinces in Washington*

Type	Olympic Peninsula and Southwestern Washington	Puget Trough	Washington Cascades: Western Slopes and Crest	Washington Cascades: Eastern Slopes	Columbia Basin	Okanogan Highlands
Lakes:						
Lowland	Western hemlock[1] Fern Lake[2]	Eutrophic Oligotrophic[7]	Typical[1]	Eutrophic	Fresh[14] Alkaline[14] Saline[14]	Mixed conifer[15]
Subalpine	Pacific silver fir[3]		Findley Lake[9] North Cascades	Oligotrophic[12]		Engelmann spruce-subalpine-fir
Alpine	Typical		Typical			
Permanent ponds:						
Lowland	Typical	Typical		Typical	Fresh[14] Alkaline[14] Saline[14]	Typical
Subalpine	Typical		Typical	Typical		Typical
Alpine	Typical		Typical			
Vernal ponds:						
Lowland	Typical			Typical	Typical	Typical
Subalpine	Typical		Typical	Typical		Typical
Alpine			Typical			
Streams:						
Lowland	Sitka spruce-western hemlock[4] Douglas-fir-western hemlock[5] Redcedar swamp[6]	Typical[8]	Mature conifer[10]	Mixed conifer[13]	Typical (Rattlesnake Creek)	Mixed conifer[15]
Subalpine	Glacial and non-glacial		Typical (Butter Creek)[11] "Milkwater" creek	Mixed conifer[13] Serpentine (El Dorado Creek)		Engelmann spruce-subalpine-fir

See footnotes at end of table.

Table 100.--*Selection criteria of aquatic cells for the six physiographic provinces in Washington* (Continued)

Type	Olympic Peninsula and Southwestern Washington	Puget Trough	Washington Cascades: Western Slopes and Crest	Washington Cascades: Eastern Slopes	Columbia Basin	Okanogan Highlands
Springs:						
Cold	Typical	Typical	Typical	Typical	Typical	Typical
Hot	Typical		Typical	Typical	Typical	
Swamp	Redcedar		Redcedar			
Marsh	Typical	Typical	Typical	Typical	Typical freshwater Typical saline	Typical
Bog	Typical	Typical	Typical	Typical		Typical

[1] Lake and drainage basin of temperate forest.
[2] Existing study area that could be designated as an RNA.
[3] Lake and drainage basin of subalpine forest and meadow.
[4] Sitka spruce-western hemlock forest and major stream drainage (west slope of peninsula). Anadromous fish run.
[5] Douglas-fir-western hemlock forest and major stream drainage (east slope of peninsula).
[6] Stream fed by redcedar swamp. Anadromous fish run. Should be combined with swamp cell.
[7] Lake in glaciated topography and drainage basin of temperate forest.
[8] Douglas-fir-western hemlock major combined terrestrial and aquatic ecosystem.
[9] Existing study area that could be designated as an RNA. No fish present. Lake recommended for North Cascades should have fish present.
[10] Temperate conifer forest and major stream drainage.
[11] Subalpine forest mosaic and major stream drainage.
[12] Mixed-conifer forest and lake.
[13] Mixed-conifer (ponderosa pine, Douglas-fir, grand fir, etc.) forest and major stream drainage. Extends through both lowland and subalpine.
[14] Series of scabland lakes of varying water chemistry with shrub-steppe communities.
[15] Mixed-conifer forest and stream drainage.

Table 101.--*Selection criteria of aquatic cells for the nine physiographic provinces in Oregon*

Type	Oregon Coast Ranges	Western Oregon Interior Valleys	Siskiyou Mountains	Oregon Cascades: Western Slopes and Crest	Oregon Cascades: Eastern Slopes	Ochoco, Blue, and Wallowa Mountains	Basin and Range, High Lava Plains and Columbia Basin, Owyhee Upland
Lakes:							
Lowland	Sand dune lake Coastal lake	Oxbow-Willamette Valley[5]	Typical	Douglas-fir-western hemlock[6] (north) Douglas-fir-western hemlock (south)		Mixed conifer	Saline (borax lake) Freshwater Playa lake
Subalpine			Typical Serpentine	Western Cascades[7] High Cascades[7]	Mixed conifer[10]	Typical	Steens Mountain
Alpine				Typical		Typical	
Permanent ponds:							
Lowland	Sand dune	Eutrophic	Typical	Northern Cascades		Typical	Saline Freshwater
Subalpine			Typical	Typical	Typical	Typical	Steens Mountain
Alpine				Typical		Typical	
Vernal ponds:							
Lowland	Sand dune	Typical	Typical	Typical		Typical	Typical
Subalpine			Typical	Typical	Typical	Typical	Typical
Alpine				Typical		Typical	
Streams:							
Lowland	Sitka spruce-western hemlock[1] Douglas-fir[2] Alder[3] Sand bottom[4]	East-side small West-side small Slough	Mixed evergreen Coniferous forest	Douglas-fir-western hemlock[8] Mixed conifer[9]		Mixed conifer	Typical
Subalpine	Typical headwaters		Serpentine	Typical	Mixed conifer[10]	Typical	Sagebrush-juniper[11]

Table 101.--*Selection criteria of aquatic cells for the nine physiographic provinces in Oregon* (Continued)

Type	Oregon Coast Ranges	Western Oregon Interior Valleys	Siskiyou Mountains	Oregon Cascades: Western Slopes and Crest	Oregon Cascades: Eastern Slopes	Ochoco, Blue, and Wallowa Mountains	Basin and Range, High Lava Plains and Columbia Basin, Owyhee Upland
Springs:							
Cold		Mineral	Cave		Metolius headwaters		Typical Malheur Cave
Hot				Typical	Typical		Typical
Swamp	Sitka spruce						
Marsh	Skunk cabbage Willow-sedge	North South	Typical	Bulrush-sedge	Typical	Typical	Tule west[12] Tule east[12]
Bog	Coastal		Coastal mountain	Subalpine	Typical	Typical	

[1]Combined with terrestrial, includes anadromous fish, includes hardwoods (alder, maple) along stream, should include a drainage directly to ocean with small estuary.

[2]Combined with terrestrial, includes hardwoods (maple, alder) along stream, includes anadromous fish--away from coast.

[3]Combined with terrestrial, includes at least two perennial streams.

[4]Central coastal plain (Florence and south)--small, stable, low gradient. Alder-salmonberry overstory; water-oriented animal refuge.

[5]Probably eutrophic.

[6]Combined with terrestrial (temperate forest).

[7]One or other should be combined with terrestrial (Crabtree Creek might fill need).

[8]Combined with terrestrial (Middle Santiam might fill need), need anadromous fish if possible.

[9]Combined with terrestrial, Abbott Creek RNA fills need.

[10]Combined with terrestrial.

[11]Combined with terrestrial, probably Steens Mountain.

[12]Western tule marsh probably around Klamath Lakes; eastern tule marsh probably around Malheur Lake.

Table 102.--*Number of filled and unfilled aquatic (freshwater) cells, by State and province*

Province	Number of filled cells	Number of unfilled cells	Total
Washington:			
Olympic Peninsula and Southwestern Washington	0	17	17
Puget Trough	1	7	8
Western Slopes and Crest, Washington Cascades	7	11	18
Eastern Slopes, Washington Cascades	0	11	11
Columbia Basin, Washington	2	11	13
Okanogan Highlands	2	9	11
Total	12	66	78
Oregon:			
Oregon Coast Ranges	0	13	13
Western Oregon Interior Valleys	1	8	9
Siskiyou Mountains	2	12	14
Western Slopes and Crest, Oregon Cascades	3	14	17
Eastern Slopes, Oregon Cascades	0	8	8
Ochoco, Blue, and Wallowa Mountains	0	13	13
Basin and Range	0	14	14
High Lava Plains and Columbia Basin, Oregon	0	6	6
Owyhee Upland	0	8	8
Total	6	96	102
TOTAL	18	162	180

REPORT OF RARE AND ENDANGERED SPECIES WORKING GROUP

In recent years, there has been much national concern for rare and endangered species. For our purposes, two types of criteria for classification of species into categories are presented: (1) criteria by which a species is selected for preservation within Research Natural Areas;[4] and (2) criteria by which to characterize a species' status.[5] Every attempt has been made to adhere to sound biological principles and objectivity. It is stressed that both sets of criteria are intended to be dynamic, amended, and updated as need dictates.

The aim of obtaining Research Natural Areas is neither strict preservation of a species in a "hands off" concept nor uncontrolled utilization as a "scientific resource." When a Research Natural Area contains a rare, uncommon, threatened, or endangered species, the Research Natural Area becomes an irreplaceable, unique, natural research laboratory. Research within a Research Natural Area is a privilege and must be conducted wisely and with the highest ethical standards.

In Research Natural Areas: (1) Species can be protected that otherwise would not receive protection; (2) species can be protected before they reach the brink of extinction; (3) species and populations can be monitored and knowledge of their requirements and status obtained; and (4) Research Natural Areas will act as refugia for species whose habitats are being destroyed.

If human population growth and land development continue as present trends indicate, sooner or later we will be faced with the prospect of deciding which species are practical to save and which will have to be allowed to decline to extinction. By protecting species, as well as diverse habitats, within Research Natural Areas now, we may be able to forestall or eliminate the necessity of some of those decisions; many or most of the less common species will be included in Research Natural Areas established for other purposes. It is anticipated that very few Research Natural Areas will be established specifically for the protection of individual species; but when necessary, a recognized authority should appraise the candidate areas to ensure the best possible selection.

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[4]These criteria are a direct result of the working group for rare and endangered species of the Research Natural Area workshop.

[5]Murray L. Johnson, Curator of Mammals, Museum of Natural History, University of Puget Sound, Tacoma, Washington, has kindly allowed the use of his unpublished "Terms Related to Populations and Survival Status of Mammals." Johnson's criteria are an excellent beginning to the development of objective criteria for characterization of a species' status. They can be adapted to animal species other than mammals. Unfortunately, as yet only the mammals in Oregon and Washington have been categorized through the use of Johnson's criteria (app. VI). Hopefully, other species will be so treated eventually. Johnson has reserved the right to publish his concepts elsewhere when they have been further refined.

Criteria by Which a Species Is Selected for Preservation Within Research Natural Areas

Taxonomic Level

The taxonomic level considered to be compatible with the concept of a minimal RNA system must remain flexible. Species and subspecies should be considered on an individual basis as needs become apparent.

Kinds of Species

Requirements for compatibility of a species or subspecies with the RNA concept are:

(1) A species must not necessitate management practices that would alter the RNA in order for the species to survive.

(2) An animal species must be neither migratory nor wide-ranging, and its entire habitat requirements must be satisfied within RNA boundaries.

(3) A population must be of sufficient size to remain viable within the RNA.

Introduced or Reintroduced Species

Introduced or reintroduced species are generally considered to be noncompatible with the RNA concept, except as noted below.

(1) Under certain circumstances, reintroductions that originate from native gene pools may be considered on an individual basis.

(2) Native species of North America that have been introduced or relocated would be considered on an individual basis if the species as a whole were determined to be endangered.

Peripheral Species

Species and, in certain instances, subspecies at the extremes of their known geographical distributions, irrespective of political boundaries, should be considered on an individual basis. Such populations are genetically and evolutionarily important because: (1) they either are adapting genetically or are genetic relics, (2) they are more constrained and influenced by their immediate environment than is the species as a whole, and (3) studies of such populations will facilitate understanding of the adaptability of the species as a whole. Other considerations are as follows:

(1) A population must be recognized as a natural resident of the area—not as transient, introduced, or relocated.

(2) It should be determined, based upon the best information, that a population's survival is threatened.

Working Inventory and Management of Adjacent Areas

A list of species and, in some cases, subspecies within a State or region should be developed at the time of RNA selection or, at the latest, establishment of the RNA. Taxons should be identified with reference to their status (see criteria for status in the two following animal and plant sections) and compatability with Research Natural Area management concepts as indicated earlier.

In certain cases, species which are noncompatible with the RNA concept, but are of special interest (rare, uncommon, etc.), may occur within a Research Natural Area. In selected instances, the region adjacent to the Research Natural Area should be managed in such a way as to ensure the survival of the species within the region with the Research Natural Area as its focal point. Management recommendations should be made on an individual basis with respect to the species and the agency concerned.

Terms Related to Populations and Survival Status of Mammals[6]

Introduction

There is a need for clearly defining the several terms that are used in lists and published articles related to "rare," "endangered," or "threatened" species. The terms defined have for years been used with impreciseness by individuals or organizations interested in and dedicated to the cause of conservation. The diversity of interest of authors creates a diversity of viewpoints. This in turn results in different meanings or interpretations of the same word.

As a person experienced and reasonably competent in the field of mammalogy, I am frequently asked for my opinion regarding the status of a species. Lists are given me for criticism, related to different accents, different purposes, and honest and thoughtful appraisal at times required qualifying statements that may be frustrating to both me and my respondent.

In the interest of better communication this paper was organized. It is to be looked upon not as anything new or different, but as a synthesis of definitions and criteria used by many experienced persons. Selection of arbitrary figures were necessary in order to establish a baseline. There is nothing of deeper significance in the numerical portions of the definitions.

"RARE" and "UNCOMMON" are more often than not terms based upon subjective bases. This situation is unsatisfactory. Because the words imply quantification, they should be clearly defined and subject to reproducible evaluation. However, there is no way that a single criterion may be used with all groups of mammals, or with other living things for that matter. This is because of the basic differences of the available methods that can be applied to any quantifying analysis, imposed by the facts of natural history of the organisms themselves.

Therefore mammals have been grouped into general categories related to methods of obtaining data:

a) Small terrestrial mammals usually observed by collecting in mouse-size or rat-size traps.
b) Larger terrestrial mammals and seals usually observed by visual means (including aerial survey) and collected by larger traps, guns or camera; game managers frequently have data on these species.
c) Bats which may be collected by nets or by a variety of means from their day-time retreats or hibernacula; exact information may be secured from bat-banders.
d) Cetaceans, the most difficult group to census, except in several outstanding examples such as the gray whale; any attempt to quantitate populations in a local or regional area is frustrating. Collecting data is available from commercial or indigenous catches, widely scattered, selective and declining. Visual observation and strandings are opportunistic and not systematically organized at this time. Appraisal of species of this group must accept a great degree of subjectivity.

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[6] This entire section is a direct quotation from an unpublished paper by Murray L. Johnson. See footnote 5.

Another serious consideration in stating relative abundance of any species is related to the amount of study and collecting efforts that have been applied to that species. A species, if intensively and expertly studied, may have more scientific specimens available than a common but less well studied species.

"ENDANGERED" and "THREATENED" are terms related to future events. As such the inherent uncertainties mitigate against quantification in establishing criteria. Although a model could be set up that would incorporate quantified data, this I believe would greatly magnify the chances of error and lessen the benefits to be derived. These terms therefore are best designated by opinions of experts. As defined here, the term "ENDANGERED" is compatible with the usage "Endangered" in the Red Book of the IUCN (International Union for Conservation of Nature) and Resource Publications of the [U.S.] Bureau of Sport Fisheries and Wildlife, U.S. Department of Interior, number 34 (1966, revised 1968) and number 114 (1973), and as listed in the U.S. Federal Register. The term "THREATENED" embodies in part the concepts suggested in Resource Publication 114 (1973). It should be particularly useful as applied to lists of States, Provinces or other restricted geographical areas.

In defining terms, the above considerations are made, these covering the major variables related to most species of mammals. However, the reader must accept with the author the varied impreciseness of the applied terms.

DEFINITIONS

Definition of Quantification

RARE: (R)

A species or subspecies is considered RARE within a State or Province when any of the following conditions exist:

a) Small terrestrial mammals
   1) Fewer than 25 specimens are in scientific collections.
   2) The present range within the State or Province is less than 10 mi² (25.9 km²).
   3) In cases of easily observed species, fewer than 25 individuals can be regularly observed during two full days field observations by one person, in an optimum habitat.
   4) In cases where intensive expert study has been done, only one individual or less can usually be secured per 500 trap nights, in optimum habitat, or when only one animal or less can usually be secured in two full days of field work by one person.

b) Large terrestrial mammals and seals
   1) Fewer than 12 specimens are in scientific collections.
   2) In cases of easily observed species, fewer than 25 individuals can be regularly observed during two full days field observations by one person, in an optimum habitat.
   3) The present range is less than 10 mi² (25.9 km²).
   4) Data from game management files indicates rarity because of direct observations, trapping or hunting.

c) Bats
   1) Fewer than 25 specimens are in scientific collections.

2) Fewer than 25 individuals can be regularly observed during two full days of field observation, in optimum habitat and season.

3) The present range is less than 10 mi^2 (25.9 km^2).

d) Cetaceans

1) In cases of smaller whales and porpoises, fewer than 5 specimens in scientific collections.

2) Fewer than two individuals can regularly be observed by a single person during two full days field observations, in optimum habitat.

3) Fewer than 2 observations from all sources per year—confirmed, identified sightings, photographs (all within 200 mile limit from shore) or strandings.

UNCOMMON: (U) A species or subspecies is considered UNCOMMON within a State or Province when any of the following conditions exist:

a) Small terrestrial mammals

1) Fewer than 50 specimens (more than 25) are in scientific collections.

2) The present range within the State or Province is less than 30 mi^2 (87.7 km^2).

3) In cases of easily observed species, fewer than 50 individuals can be regularly observed during two full days field observations by one person, in an optimum habitat.

4) In cases where intensive expert study has been done, only one individual or less can usually be secured per 200 trap nights in optimum habitat, or when only one animal can usually be secured in one full day of field work.

b) Large terrestrial mammals and seals

1) Fewer than 25 specimens are in scientific collections.

2) In cases of easily observed specimens: fewer than 25 individuals can regularly be seen during one full day of field observation in an optimum habitat.

3) The present range is less than 30 mi^2 (87.7 km^2).

4) Data from game management files indicate unusual status because of direct observations, trapping or hunting.

c) Bats

1) Fewer than 50 specimens are in scientific collections.

2) Fewer than 50 individuals can be regularly observed during one full day of field observation, in optimum habitat and season.

3) The present range is less than 30 mi² (87.7 km²).

d) Cetaceans
   1) In cases of smaller whales and porpoises: fewer than 10 specimens in scientific collections.

   2) Fewer than 2 individuals can regularly be observed during one day of field observation, in optimum habitat.

   3) Fewer than 4 observations from all sources per year; confirmed, identified sightings, photographs (within 200 mi from shore) or strandings.

Definitions Related to Survival

ENDANGERED: (E) Any species or subspecies considered likely to become extinct in its total range during the next 10 years if present trends continue. Related to population estimates and dynamics, and to habitat destruction.

THREATENED: (TH) Any species or subspecies not on the ENDANGERED list, but which is considered likely to be extirpated from a localized area such as a State or Province or lesser area within the next 10 years if present trends continue.

EXTINCT: (EX) Any species or subspecies that has not been reliably reported within any State or Province during the past 10 years, and which may be reasonably considered extinct by reason of reliability of information and state of knowledge that exists regarding the species.

Qualifying Definitions

STATUS UNDETERMINED: (SU) May be appended to any designation in cases where up-to-date information is not available or where the status information is especially suspect or tenuous.

PERIPHERAL: (P) May be appended to any designation in cases where the species has a major or extended range in a contiguous State or Province. PERIPHERAL is of biological importance when the locality represents the extreme of range or an isolated island of population; it is of political importance only when it represents an incidental crossing of border.

ACCIDENTAL: (A) May be appended to any designation whenever the situation logically suggests that an individual observation or collection was the result of wandering beyond a natural range.

UNIQUE: (UN) May be appended to any designation whenever the range of the species or subspecies lies entirely within a given political boundary such as a State or Province.

APPLICATION OF TERMS TO OTHER GROUPS OF ORGANISMS

Although the definitions and criteria noted in this paper are primarily related to mammals of the North Pacific area of North America, they may with similar benefit be applied to other organisms and other areas. For instance, other terrestrial plants and animals may be assigned RARE or UNCOMMON status by applying the criteria for small terrestrial mammals. Species of birds may appropriately be classified as under small or large terrestrial mammals. Definitions of survival and qualifying definitions should not be significantly different for any biologic group.

SUMMARY STATEMENT

Terms are defined and the criteria are suggested that will help to unify reference to rare and endangered species of mammals. It is to be stressed that this subject is dynamic and status of any form may change in a single year. Continued re-evaluation is necessary for proper use of the definitions suggested.[7]

Vascular Plants of Special Interest

Vascular plants of special interest are approached on a somewhat different basis from vertebrate animals.[8] There are many more plant than animal species of unique interest. Lists were compiled for each State by botanists from literature and herbarium surveys and questioning of professional and amateur botanists familiar with the region. Additional suggestions came from preliminary editions of the national list of threatened and endangered plants (Smithsonian Institution 1974).

Criteria used to select plants of special interest were the following:

A. Rare
   1. Range limited and circumscribed
      a. Local endemic (found only in a small area, e.g., a single mountain)
      b. Regional endemic (found only in a region, e.g., Siskiyou Mountains)
      c. Disjunct population (widely separated from main body of a species' range)
      d. Marginal population (at edge of species' range, including outliers)
   2. Range widespread but with relatively few individuals per site or relatively few sites or both

[7] End of Johnson quotation.

[8] Only vascular plants are considered at this time; necessary information on other plant groups could not be accumulated easily or is incomplete.

B. Endangered
   1. Habitat being destroyed, e.g., by agricultural or hydroelectric developments
   2. Plants being destroyed, e.g., by collectors or selective grazing

These criteria could be used in only a general way, however, because the real status of many plants is unknown. Furthermore it was not possible to do field checks for verification of presumed status.

Complete lists are presented of vascular plants of special interest which were developed for each province. This has been done for a variety of reasons. First, land managers in each area need a single reference to all vascular plants presently known or believed to be worthy of special attention in planning and management activities. Second, unusual species should be identified which can be considered in selection of Research Natural Areas representative of terrestrial and aquatic ecosystems and incorporated as adjunct elements. Third, areas must be designated where concentrations of special interest plants warrant selection and establishment of Research Natural Areas specifically for their protection and study.

The purpose of these lists is to summarize present knowledge on the status of vascular plant species, stimulate interest, solicit information, and thus, hopefully, to improve chances of survival for the plants of interest. They do not constitute unofficial or official lists of "endangered" plants. The only indication of "status" we have provided, other than to describe the group in general as special interest or rare and endangered plants, is identification of those plants included in the Smithsonian list (Smithsonian Institution 1974). These are proposed for, and by the time this report appears may have received, official designation as Threatened or Endangered species under the Endangered Species Act of 1973. We also assume that individuals engaged in selection of Research Natural Areas for terrestrial and aquatic interest will try to incorporate populations of special interest species when possible.

None of the plants listed have been identified as essential elements or cells in a system of Research Natural Areas. A majority of the species could probably be included in the sense that maintenance of viable populations would not require activities incompatible with the Research Natural Area concept. However, only a subset of these compatible species requires a strict reserve of this nature for their protection and study.Many can be preserved in National and State Parks,Botanical Areas, Wilderness and other roadless areas, etc., provided that they are recognized and accommodated in management plans for these tracts. What we have done is to identify the need for Research Natural Areas in several areas where there are concentrations of special interest plants, particularly those on the Smithsonian list which have some official status as Threatened and Endangered. Among the most notable of these areas are the Columbia River Gorge (listed in four provinces), Siskiyou Mountains, Wenatchee Mountains, Snake River Canyon, Owyhee Canyon, and northeastern Olympic Peninsula.

Frequent reevaluation of the lists of special interest plants with additions and deletions is expected. In fact, periodic evaluations are viewed as essential if the lists are to reflect our current knowledge regarding distinctive species in our regional flora.

Nomenclature of plants generally follows that of Hitchcock et al. (1955-69) supplemented by Peck (1961) in southern Oregon. A few species are not described in either.

Part V. Conclusions and Recommendations

In the course of deliberations the workshop participants surfaced a variety of concerns relating to implementation of the Research Natural Area recommendations. These relate to actual selection of areas, use of established Research Natural Areas, considerations of scientific values in management of areas which are not dedicated to research, and resolution of some problems regarding how some types of aquatic tracts should be dealt with.

SELECTION OF AREAS

It is clear that the major task is to get on with identification and dedication of areas which satisfy the remaining Research Natural Area needs. While the program in the Pacific Northwest has been progressing well, a great deal remains to be done. Hopefully this document makes clear the extent of the task as well as the priorities with regard to ecosystem types, ownerships, and geographic regions. A consideration of the existing system makes clear the most glaring deficiencies in the system with regard to each of these items. For example, marine ecosystems are almost totally lacking in the existing system, freshwater ecosystems are only a little better off, and even in the case of terrestrial types, great gaps exist in the steppes east of the Cascade Range, the heavily populated Puget Trough and Western Oregon Interior Valleys, and in southwestern and eastern Oregon.

Consequently, we believe that all participants should greatly expand their efforts aimed at identifying and reserving the needed areas. It is feasible to suggest a goal of 50 percent completion of the system in 5 years and 80 to 90 percent in 10 years.

It is also clear that selection of areas will require more effort than has been typical in the past. For example, in many cases it has become apparent that the wisest course is, when possible, to select areas which incorporate as many cells or needs as possible. That is, we should be looking for areas with a greater variety of ecosystems, habitats, and organisms rather than looking for an area representative of a single feature.

The selection of multiple-cell Research Natural Areas has several implications. For one thing we will often be seeking larger individual tracts than would have been the case with single-feature areas. As the size and consequent land investment increase, it must be more clearly established that the selected tract is the best area available. Therefore evaluation of a proposed tract should include a representation of more scientific disciplines and better documentation of the scientific values before it is established.

We recommend that, insofar as possible, tracts proposed for multicellular Research Natural Areas be evaluated by teams or individuals representing the several disciplines appropriate to each cell (e.g., limnologist, terrestrial plant and animal ecologists, soil scientist).

Care in selection should include the very important consideration that Research Natural Areas should be established on soils and landforms representative of broad land segments. It is only in this way that they can realize their full potential as baseline or control areas and that results of research can have their widest application. Even though individual soils and landforms are not recognized as cells in this report, the need for attention to these elements is considered implicit and is aided through designation of subprovince location in the natural area needs listings (pt. II).

Two steps are proposed to assist in assuring representation of soils and landforms. First, we recommend that the U.S. Department of Agriculture, Forest Service, the Soil Conservation Service, and other agencies conducting soil-landform surveys be encouraged to provide, as data become available, a tabulation of the soil type-landform mapping units on the ownerships they are surveying and their importance (acreage). Second, soils and landforms should be adequately described as part of the documentation process on proposed Research Natural Areas.

The increased concern for representation of aquatic systems and rare and endangered animals as well as important soils and landforms leads us to encourage the agencies to improve their knowledge of existing Research Natural Areas. There is clearly a need to know better what is already protected, and the Federal agencies are to be commended for their recent efforts along these lines.

Related to the additional study of existing Research Natural Areas is the need to reexamine several of the older tracts to determine whether boundaries can be adjusted to provide new or better representation of additional cells. Many of the early areas were set up with a single community or ecosystem in mind; with alteration, they could serve several needs.

All of this can be summarized by a recommendation to take a retrospective look at what is already preserved as Research Natural Areas and determine if adjustments are desirable to increase the areas' value.

The emphasis on multicellular Research Natural Areas should not obscure the fact that many, if not the majority, of Research Natural Areas will be smaller areas focused on single ecosystems or habitats. Much work remains to be done in identifying and dedicating these types of areas. Similarly, excessive pursuit of an ideal area, which contains many cells, must not be allowed to become a major roadblock. It may not be possible to locate an ideal area as hypothesized in the listing, and the involved agencies and scientists should be prepared to alter cellular makeups as necessary.

RARE AND ENDANGERED ORGANISMS

Much work remains to be done in identifying the best way to handle rare and endangered organisms, particularly plants. We were able to largely resolve the needs insofar as rare and endangered vertebrates are concerned, i.e., identify those which can and should be handled in a Research Natural Area context and those which cannot. The situation is much less clear with regard to invertebrates and plants; we lack even acceptable lists for many of these organisms.

There are several important items to keep in mind as we proceed in the future. First of all, there must be close coordination with the threatened and endangered organism program of the U.S. Department of Interior, Fish and Wildlife Service. The national program is developing lists which we can use as a working base in regional programs; two of these have been used in preparing this document.

At least as important is the recognition that many of the rare and endangered plants and, perhaps, invertebrates can be protected by a variety of procedures short of establishing Research Natural Areas specifically for them. Included are identified tracts open to a wider array of uses but within which management is designed to protect the rare and endangered populations—Botanical Areas, State and National Parks, and Wilderness Areas, as examples. The scientist should make the land manager aware of a valid rare and endangered organism and advise measures necessary for its perpetuation which will often be compatible with many other uses. Awareness is one reason for the extensive tables on vascular plants of special interest.

Many rare and endangered organisms are, of course, already protected in Research Natural Areas and more should be. Therefore, what remains to be done? First, we need improved knowledge of the rare and endangered organisms which may be present in Research Natural Areas. This goes back to the earlier recommendation for better descriptions of the natural features of existing Research Natural Areas.

With regard to scientific use of Research Natural Areas there are, however, some special management problems. Theoretically, all research use of these reserves is approved by the managing agency, and approval is held to those studies which will not significantly alter the natural feature or natural processes affecting it. We believe some guidance to institutions would be helpful in evaluating proposed research on rare and endangered organisms and, indeed, all animal studies. These guidelines should not be construed as overly restrictive. Rather, they are intended to protect the species of interest while at the same time insuring the proper accumulation of knowledge and maintaining the individual freedom of the researcher.

Suggested guidelines follow.

1. In addition to the agency personnel and the appropriate Research Natural Area Committee, a recognized authority should review each research proposal to determine the following:
   a. Is the study worthwhile?
   b. Will the type of study be compatible with the survival of the species?
   c. Does the study necessitate the removal of specimens (collecting)?
   d. How many specimens can be removed without endangering the survival of the population?
2. If specimens are to be collected, the proper permits (State, Federal, etc.) should be required.
3. Minimum standards of data recording should be required.
4. All possible data should be gathered, recorded, and preserved with respect to the particular species that Research Natural Area has been established to protect.
5. All individuals of the particular species which the Research Natural Area has been established to protect should be prepared as proper specimens; such specimens should be placed in a bona fide repository. The location of the specimens as well as pertinent data should be on file with the proper agency for other students to use.

6. A file of all research proposals should be maintained to insure that studies conducted on a particular species, within a particular Research Natural Area, are such that knowledge is enhanced and that unnecessary duplication is avoided.
7. Copies of articles resulting from studies conducted within a Research Natural Area should be required and maintained in a central library.
8. Long-term, nondestructive studies for Rare, Uncommon, Threatened, or Endangered species should be encouraged within Research Natural Areas.

We strongly recommend that the rare and endangered species component of the Research Natural Area program be closely coordinated with the Fish and Wildlife Service's program under the new Endangered Species Act. Beyond this, working relationships should be developed with the State game departments for fur-bearing and nongame animals. Cooperative working relationships should be developed so that these departments are completely aware of the Research Natural Areas, their purpose and location, and so that they are closed to nonconforming, animal-removal activities.

AQUATIC AREAS

As mentioned earlier, progress has been slowest in establishment of aquatically oriented Research Natural Areas. Several serious conceptual problems remain also. We never resolved the question of how examples of the aquatic communities of large river systems can be preserved for study. Setting aside river segments can do the job for riparian biota but will not satisfactorily preserve the river community itself. One suggestion was that it may be possible to provide examples of such ecosystems for study in the context of Wilderness Areas or of Wild and Scenic Rivers. This may well be the case, but if so, exemplary rivers should be identified so both managers and scientists are aware of them and their specific scientific values.

Perhaps more relevant to the natural area program is the question of whether it is necessary to protect the complete drainage of a lake, pond, or stream before it is acceptable as a Research Natural Area. There was no question that such a situation is preferred, i.e., control of the complete watershed. However, it might be possible to accept something less, depending upon the surrounding topography, use of adjacent lands, etc. Perhaps this question can be resolved on a case-by-case basis, but the Steering Committee may also wish to ask for general advice from a group of aquatic biologists.

USING RESEARCH NATURAL AREAS

Research Natural Areas are already receiving a surprising amount of use in the Pacific Northwest (app. II). However, certain types of research use require encouragement, and any use requires careful monitoring to insure it is nondestructive. As already mentioned, one of the greatest needs is for better knowledge of the organisms and ecosystems found in existing Research Natural Areas. We would go further, however, and suggest agencies and institutions

should be strongly encouraged to establish baseline study plots, e.g., permanent vegetation plots and photo points, in existing Research Natural Areas, so that they can better function as controls. Further, we would encourage agencies involved in surveys of vegetation, soil, landforms, etc., to give high priority to inventories and mapping of Research Natural Areas. In summary, baseline studies of all types should be given first priority for any funding and first priority as candidates in baseline monitoring and inventory.

In order to provide the necessary coordination of research activities on natural areas, the Steering Committee should consider ways of establishing a central file, library, or data bank on existing Research Natural Areas. This would also provide a source of information for land managers and scientists for both research and management purposes.

Finally, the review of proposals for scientific use of Research Natural Areas should be considered. The question of conforming or nonconforming use is not as clear as it seems. What can be tolerated in the research use of one area (collections, soil pits, litter treatment) is unacceptable in another. The biota, habitat, size, and topography of the area are among the several considerations. Agencies or other groups responsible for natural areas should consider establishment of ad hoc or formal advisory bodies of scientists to advise them as to the merit and appropriateness of borderline research proposals.

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APPENDIX I.

AREAS UNDER SERIOUS CONSIDERATION FOR DESIGNATION AS FEDERAL RESEARCH NATURAL AREAS

Name	Principal features	Responsible agency[1]
Bachelor Island	Black cottonwood-willow stands on part of island in Columbia River	FWS
Beatty Creek	Jeffrey pine near northern range limits in southwestern Oregon	BLM
Boulder Creek	Ponderosa pine/bunchgrass forest on steep, granitic stream drainage on eastern slopes of northern Washington Cascade Range	FS
Cannon Wells	Lodgepole pine/bitterbrush forest on coarse Mazama pumice east of Crater Lake	FS
Cougar Butte	Mountain meadow and associated vegetation along Rogue-Umpqua River divide in southwestern Oregon	FS
Crabtree Lake	Subalpine lake and drainage and western redcedar forest on western slopes of Oregon Cascade Range	BLM
Eldorado Creek	Serpentine area in Wenatchee Mountains on eastern slopes of Washington Cascade Range	FS
Flynn Creek	Stream drainage in Oregon Coast Ranges with anadromous fish and second-growth Douglas-fir forest	FS

[1] BLM= Bureau of Land Management, FS= Forest Service, NPS= National Park Service, FWS= Fish and Wildlife Service.

Name	Principal features	Responsible agency[1]
Government Draw	Mosaic of grassland and coniferous forest communities in Wallowa Mountains of northeastern Oregon	FS
Green Mountain	Subalpine meadows and parkland on western slopes of northern Washington Cascade Range	FS
Head of Little Blitzen Gorge	Bunchgrass steppe and associated vegetation over 3,000-foot elevation range	BLM
Hunter Creek Bog	Bog community along Oregon Coast	FS-BLM
Jordan Craters	Area of Pleistocene volcanic activity, shrub-steppe, and lakes and ponds in southeastern Oregon	BLM
Kiger Gorge Plateau	Bunchgrass steppe over 2,000-foot elevational range	BLM
Middle Santiam	Old-growth Douglas-fir-western hemlock forest and stream drainage on western slopes of Oregon Cascade Range	FS
Moore Flat	Mixed-conifer forest, including ponderosa pine, Douglas-fir, and grand fir in Blue Mountains	FS
Mountain Hemlock	Stands of mountain hemlock and associated ponds along crest of Oregon Cascade Range near Waldo Lake	FS
North Hunting Island	Black cottonwood-Sitka spruce-willow community on island in lower Columbia River	FWS
Store Gulch	Mixed-evergreen forest and stream drainage along Illinois River on east slopes of Siskiyou Mountains in southwestern Oregon	FS
Swakane Canyon	Rare *Trifolium thompsonii* and associated meadow on eastern slopes of northern Washington Cascade Range	FS
The Island	Western juniper and big sagebrush on isolated plateau in Deschutes River of eastern Oregon	BLM-FS
Tiffany Mountain	Subalpine larch, alpine meadows, and ponds on eastern slopes of northern Washington Cascade Range	FS
Twin Creek	Enlarged area to include stream drainages in Sitka spruce-western hemlock forests on western slopes of Olympic Mountains	NPS
Twinbutte Creek	Southwestern Oregon mixed-conifer forest in South Umpqua River drainage	FS
Wickiup Springs	Shasta red fir forest over an elevational range on western slopes of southern Oregon Cascade Range	FS

[1] BLM= Bureau of Land Management, FS= Forest Service, NPS= National Park Service, FWS= Fish and Wildlife Service.

APPENDIX II.
PARTIAL LIST OF PAST AND CURRENT STUDIES ON RESEARCH NATURAL AREAS

Research Natural Area	Subject of study	Status	Institution
Abbott Creek	Vegetation classification of southwestern Oregon mixed-conifer forests	Completed	Oregon State University
Bluejay	Classification of ecosystems of Mazama pumice region	Current	U.S. Forest Service
Butter Creek	Classification of subalpine meadow communities of Washington Cascades	Current	Oregon and Utah State Universities
Coquille River Falls	Progression of *Phytophthora* root rot	Current	Oregon State University
	Ecology of Port-Orford-cedar	Current	Oregon State University
Goat Marsh	Productivity analysis of superlative noble fir stand	Current	Coniferous Forest Biome (IBP)
Gold Lake Bog	Taxonomy of frogs	Completed	Oregon State University
Horse Ridge	Baseline bird and mammal populations in juniper savanna	Current	U.S. Fish and Wildlife Service
	Classification of juniper forests of eastern Oregon	Completed	U.S. Forest Service
Jackson Creek	Study of Olympic rain forest	Current	Western Washington State College
Little Sink	Floral and faunal studies of Willamette foothill forests and ponds	Current	Oregon College of Education
Lost Forest	Characteristics and explanation of the disjunct pine forest	Completed	Oregon State University
Maple Knoll	Bird communities in Willamette Valley forest communities	Completed	Oregon State University
Meeks Table	Range communities of Meeks Table	Completed	U.S. Forest Service
	Soils of eastern Washington Cascade Range	Current	U.S. Forest Service

Research Natural Area	Subject of study	Status	Institution
Metolius	Environmental effects on forest productivity	Current	Coniferous Forest Biome (IBP)
Neskowin Crest	Mammals of the Oregon coast	Current	University of Puget Sound
North Fork Nooksack	Characteristics of litter layers in northwestern forests	Completed	University of Washington
Ochoco Divide	Classification of the forests of the Blue Mountain region	Completed	U.S. Forest Service
Olallie Ridge	Disjunct flora of Oregon Cascades	Completed	University of Oregon
Pigeon Butte	Bird communities in Willamette Valley forest communities	Completed	Oregon State University
Port Orford Cedar	Progression of *Phytophthora* root rot	Current	Oregon State University
	Ecology of Port-Orford-cedar	Current	Oregon State University
Pringle Falls	Litter decomposition in pine forests	Current	Coniferous Forest Biome (IBP)
	Growth of ponderosa and lodgepole pine forests	Completed	U.S. Forest Service
	Seed production by ponderosa and lodgepole pine	Current	U.S. Forest Service
	Baseline bird and mammal population in ponderosa and lodgepole pine forests	Current	U.S. Fish and Wildlife Service
Rainbow Creek	Insect studies in larch forests	Current	U.S. Forest Service
Rattlesnake Hills	Variety of studies including productivity and cycling in different ecosystems, environment-community relationships, meteorology, vertebrate and invertebrate populations, food habits, hydrology, geology, soils, effects of burning on ecosystems, succession	Current	Battelle Memorial Institute, Energy Research and Development Administration, Washington State University, Grassland Biome (IBP)
	Plant communities of the Columbia Basin	Completed	Washington State University

Research Natural Area	Subject of study	Status	Institution
Sister Rocks	Classification of subalpine communities in southern Washington	Completed	U.S. Forest Service
Steamboat Mountain	Cone and seed production by subalpine fir	Current	U.S. Forest Service
	Growth and succession in subalpine fir forest	Current	U.S. Forest Service
	Classification of subalpine communities in southern Washington	Current	U.S. Forest Service
Twin Creek	Vegetative study of Olympic rain forest	Current	Western Washington State College
Wheeler Creek	Mammals of the Oregon coast	Current	University of Puget Sound
Wildcat Mountain	Cone and seed production by noble and silver firs and mountain hemlock	Current	U.S. Forest Service
	Litter fall and decomposition in true fir-hemlock forests	Current	Coniferous Forest Biome (IBP)
	Productivity and nutrient balance in true fir-hemlock forests	Current	Coniferous Forest Biome (IBP)
	Classification of Oregon Cascade forest communities	Current	U.S. Forest Service
	Environment-forest community relationships in Oregon Cascade Range	Current	Coniferous Forest Biome (IBP)
	Distribution of vertebrate animals in relation to forest communities and environment	Current	Coniferous Forest Biome (IBP)
Willamette Floodplain	Composition, succession, and productivity in Willamette grasslands	Current	U.S. Forest Service, U.S. Fish and Wildlife Service
	Small mammal populations in Willamette prairies	Current	U.S. Forest Service, U.S. Fish and Wildlife Service
Wind River	Growth and mortality in old-growth Douglas-fir-hemlock forest	Current	U.S. Forest Service
	Seed survival of Douglas-fir in forest floor	Completed	U.S. Forest Service

APPENDIX III.

WASHINGTON LEGISLATION ON RESEARCH NATURAL AREAS

HOUSE BILL NO. 482

State of Washington
42nd Legislature

by Representatives North,
Moon and Cunningham

Second Extraordinary Session
Read first time January 19, 1972, and referred to Committee on Natural Resources and Ecology

AN ACT Relating to natural resources: and adding a new chapter to Title 79 RCW.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF WASHINGTON:

NEW SECTION. Section 1. The purpose of this chapter is to establish a state system of natural area preserves and a means whereby the preservation of these aquatic and land areas can be accomplished.

All areas within the state, except those which are expressly dedicated by law for preservation and protection in their natural conditions, are subject to alteration by human activity. Natural lands, together with the plants and animals living thereon in natural ecological systems, are valuable for the purposes of scientific research, teaching, as habitats of rare and vanishing species, as places of natural historic and natural interest and scenic beauty, and as living museums of the original heritage of the state.

It is, therefore, the public policy of the state of Washington to secure for the people of present and future generations the benefit of an enduring resource of natural areas by establishing a system of natural area preserves, and to provide for the protection of these natural areas.

NEW SECTION. Sec. 2. For the purposes of this chapter:

(1) "Department" shall mean the department of natural resources.

(2) "Natural areas" and "natural area preserves" shall mean such public or private areas of land or water which have retained their natural character, although not necessarily completely natural and undisturbed, or which are important in preserving rare or vanishing flora, fauna, archaeological, natural historical or similar features of scientific or educational value.

(3) "Public lands" and "state lands" shall have the meaning set out in RCW 79.01.004.

(4) "Committee" shall mean the Washington state natural preserves advisory committee created in section 5 of this chapter.

NEW SECTION. Sec. 3. In order to set aside, preserve and protect natural areas within the state, the department is authorized, in addition to any other powers, to:

(1) Establish by rule and regulation the criteria for selection, acquisition, management, protection and use of such natural areas;

(2) Cooperate and contract with any federal, state, or local governmental agency, private organizations or individuals in carrying out the purpose of this chapter;

(3) Acquire by gift, device, purchase, grant, dedication, or means other than eminent domain, the fee or any lesser right or interest in real property which shall be held and managed as a natural area; and

(4) Acquire by gift, device, grant or donation any personal property to be used in the acquisition and/or management of natural areas;

(5) Inventory existing public, state and private lands in cooperation with the committee to assess possible natural areas to be preserved within the state.

NEW SECTION. Sec. 4. The department is further authorized to purchase, lease, set aside or exchange any public land or state-owned trust lands which are deemed to be natural areas: PROVIDED, That the appropriate state land trust receives the fair market value for any interests that are disposed of: PROVIDED, FURTHER, That such transactions are approved by the board of natural resources.

An area consisting of public land or state-owned trust lands designated as a natural area preserve shall be held in trust and shall not be alienated except to another public use upon a finding by the department of natural resources of imperative and unavoidable public necessity.

NEW SECTION. Sec. 5. A Washington state natural preserves advisory committee is hereby created within the department of natural resources to assist the department in carrying out the intent of this chapter. Such committee shall consist of seven members appointed by the commissioner of the department. Any vacancies shall be filled in the same manner. Members shall be chosen from persons with an interest in the establishment of natural areas and shall serve a period of three years.

NEW SECTION. Sec. 6. Nothing in this chapter is intended to supersede or otherwise affect any existing legislation.

Passed the House February 16, 1972.

Speaker of the House.

Passed the Senate February 12, 1972.

President of the Senate.

Approved February 24, 1972

Governor of the State of Washington

APPENDIX IV.

OREGON LEGISLATION ON RESEARCH NATURAL AREAS

OREGON LEGISLATIVE ASSEMBLY—1973 REGULAR SESSION

HOUSE BILL 2232

Ordered by the Senate June 23

(Including Amendments by House Committee on Environment and Land Use March 22 and by Senate June 5 and June 23)

Sponsored by Representatives INGALLS, PAULUS, PERRY, FADELEY, KATZ, WHITING

Authorizes State Land Board to establish natural area preserves for educational and scientific use of natural areas. Defines "natural area." Provides that no land be included within natural area unless it is in public ownership on effective date of Act or is acquired after effective date of Act by method requiring no expenditure of public funds for acquisition. Prohibits use, by board, of condemnation to acquire lands or interests therein for natural area preserves. Prescribes procedures for establishment of natural areas under jurisdiction of board or by agreement with other public agency. Creates Natural Area Preserves Advisory Committee within board to assist board in carrying out Act. Provides for composition, term, and compensation of committee members.

Establishes Natural Area Preserves Account. Appropriates moneys in account for purpose of carrying out this Act.

A BILL FOR AN ACT

Relating to the preservation of natural areas; and appropriating money.

Be it Enacted by the People of the State of Oregon:

SECTION 1. (1) The Legislative Assembly finds that all public lands and waters within the state that constitute natural areas are subject to alteration by human activities unless such public lands and waters are preserved and protected for the use and benefit of the people of this state. The Legislative Assembly further finds that natural areas are valuable to the people of this state for educational and scientific uses, for habitats for plant, animal, and marine species, for the preservation of the paleontological resources and the natural historic features of such public lands and waters, for public benefits from the features of such public lands and waters and for the purpose of preserving such public lands and waters as living museums of the natural heritage of this state.

(2) The Legislative Assembly, therefore, declares that it is the public policy of the State of Oregon to secure for the people of this state the benefits of an enduring resource of natural areas by establishing a system of natural area preserves and by providing for the management and protection of such natural area preserves.

SECTION 2. As used in this Act, unless the context requires otherwise:

(1) "Board" means the State Land Board.

(2) "Committee" means the Natural Area Preserves Advisory Committee created in section 3 of this Act.

(3) "Natural area" includes land and water that has substantially retained its natural character and land and water that, although altered in character, is important as habitats for plant, animal or marine life, for the study of its natural historical, scientific or paleontological features, or for the appreciation of its natural features.

SECTION 3. (1) There hereby is created a Natural Area Preserves Advisory Committee as an advisory committee to the State Land Board. The committee shall assist the board in carrying out the provisions of this Act.

(2) The committee shall consist of seven members appointed by the Governor. Of the seven members appointed by the Governor to the committee, one member shall be an individual with an advanced degree in botany, one member shall be an individual with an advanced degree in zoology, one member shall be an individual with an advanced degree in aquatic biology, one member shall be an individual with an advanced degree in geology and three members shall be individuals interested in the preservation of natural areas in this state.

(3) In addition to the seven members appointed by the Governor, the State Game Director, the State Forester, the Administrator of Highways and the Chancellor of the State Board of Higher Education or an authorized representative of each such officer, shall serve as ex officio, nonvoting members of the committee.

(4) The term of office of a member, appointed under subsection (2) of this section, is three years, but each such member serves at the pleasure of the Governor. Before the expiration of the term of each such member, the Governor shall appoint a successor whose term of office begins on July 1 next following. A member, appointed under subsection (2) of this section, is eligible for reappointment. If there is a vacancy for any cause, the Governor shall make an appointment to become immediately effective for the unexpired term.

SECTION 4. (1) In carrying out the provisions of this Act, the board, with the advice of the committee, and within available funds, may:

(a) Adopt, in accordance with the applicable provisions of ORS chapter 183, rules that it considers necessary in carrying out this Act;

(b) Adopt policy guidelines for its use in the selection, acquisition, management, protection and use of public lands included within the boundaries of natural area preserves established under section 5 of this Act; and

(c) Conduct a survey of lands in this state to locate lands that it considers suitable for inclusion within a natural area preserve established under this Act and maintain a registry of such lands.

(2) In carrying out the provisions of this Act, the board may:

(a) Cooperate and contract with any federal, state or local governmental agency or private organization;

(b) Acquire by gift, devise, grant, dedication or other method, other than by the exercise of the power of eminent domain, any private or public land or interest therein for inclusion in a natural area preserve established under this Act;

(c) Acquire by gift, devise, grant, dedication or other method, other than by the exercise of the power of eminent domain, any personal property that the board considers necessary;

(d) Apply for and accept grants, contributions and assistance from any federal, state or local governmental agency and any private foundation; and

(3) Perform other duties considered by it to be necessary in carrying out this Act.

SECTION 5. (1) With the advice of the committee, the board, in compliance with ORS chapter 183, may:

(a) Establish, by order, natural area preserves on lands in public ownership composed of contiguous lands; and

(b) Change the boundaries of natural area preserves and alter the uses and conditions for use of such preserves upon a finding by it that such change or alteration is necessary in carrying out the purposes of this Act.

(2) Each order of the board establishing a natural area preserve shall contain a legal description of the lands within the preserve, the reasons for the establishment of the preserve, any conditions upon the use of the lands in the preserve and other matters that the board considers necessary. Each such order shall be in compliance with the policy guidelines adopted by the board under paragraph (b) of subsection (1) of section 4 of this Act.

(3) The lands within a natural area preserve established under subsection (1) of this section shall be held for public use as may be specified by the board. Such lands may not be leased, sold, exchanged or otherwise transferred by the board except for another purpose upon a finding by the board, after consultation with the committee, of imperative and unavoidable necessity.

SECTION 6. (1) The board may enter into agreements with any public agency, having public lands suitable for inclusion within a natural area preserve under its jurisdiction, for the inclusion of such lands within a natural area preserve.

(2) Each such agreement shall specify the term of the agreement, the uses and conditions for the use of the public land as a part of a natural area preserve and a finding by the board and the public agency that the use of the public land subject to the agreement as a part of a natural area preserve is in the best interests of the people of this state. Each such agreement shall establish the respective responsibilities of the board and the public agency in the management and protection of such land.

(3) The board may include within the boundaries of a natural area preserve any state-owned lands under its jurisdiction.

SECTION 7. (1) All agencies, departments, boards and commissions of this state shall cooperate with and assist the State Land Board in carrying out this Act.

(2) The Legislative Assembly declares that the inclusion of suitable state-owned lands within natural area preserves constitutes a valid public purpose for the use of such lands.

SECTION 8. The Natural Area Preserves Account is established within the General Fund of the State Treasury. All moneys in the account are continuously appropriated for the use of the board in carrying out this Act.

SECTION 9. No land shall be included within a natural area unless it is either:

(1) In public ownership on the effective date of this Act; or

(2) Is acquired after the effective date of this Act by gift, devise, grant, dedication or other method requiring no expenditure of public funds for the acquisition.

APPENDIX V.

A CLASSIFICATION OF GEOMORPHIC PROVINCES AND SUBPROVINCES FOR OREGON AND WASHINGTON

It is important that the Research Natural Area System represent the major landforms and soil types found in Oregon and Washington. That is, in selecting areas representative of different terrestrial and freshwater ecosystems, topography and soils should be considered and weighted toward areas typical of broader areas. In this way the baseline data and research findings from a Research Natural Area can be more readily extrapolated to the extensively managed areas of similar type. As a first step toward insuring good representation of geologic and edaphic features, we have related many of the listed Research Natural Area needs to the geomorphic classification of the region outlined below. The system has been developed and is being used by the Pacific Northwest Region (Region 6), U.S. Forest Service, and was provided by John Corliss of that office.

Olympic Province

Character type reflects extensive glaciation. All main river valleys are broad and U-shaped, while major peaks are ringed with cirques, many containing active glaciers. Extremely high precipitation has caused rapid downcutting by streams and with glaciation has resulted in precipitous mountain slopes. These rugged mountains provide a central core surrounded by almost level lowlands which have resulted from deposition of glacial outwash.

Subprovince code No.	Description
0101	Glaciated, steep, long mountain slopes (National Park)
0102	Glaciated, steep, long mountain slopes, timbered (Shelton Ranger District)
0103	Glaciated, steep, long, dissected mountain slopes, timbered (Forks Burn area)
0104	Coastal plain (Lapush)
0105	Subalpine and alpine peaks

Coast Range Province

This character type reflects steep mountain slopes with ridges that are often extremely sharp. The ridge system is usually parallel to the coast but, being extremely dissected, often appears confused. The topography varies from nearly level along the dunal sheet, to abrupt and steep along the western edges, to more gentle along the eastern fringes. Scattered peaks, often barren, rise well above surrounding ridges.

Subprovince code No.	Description
0201	Coastal headlands (Cascade Head)
0202	Rounded, dissected mountain slopes (Willapa Hills)
0203	Short, highly dissected mountain slopes (Smith River)
0204	Steep, long mountain slopes (Mount Hebo)
0205	Complex of steep, dissected, and uneven mountain slopes (Mapleton Ranger District)
0206	Steep, long mountain slopes (Tillamook volcanics)
0207	Dunal sheet (Dunes National Recreation Area)

Siskiyou Province

This character type reflects an ancient and now greatly dissected, uplifted plain; however, some peaks rise above this dissected surface.

Subprovince code No.	Description
0301	Drainage basin (Medford-Grants Pass)
0302	Steep, uneven, dissected mountain slopes (Powers Ranger District)
0303	Steep, long mountain slopes (Mount Ashland)
0304	Steep, uneven, highly dissected mountain slopes (Mineral Hill)
0305	Steep, uneven mountain slopes
0306	Steep, long, highly dissected mountain slopes

Puget Sound Basin Province

Character type reflects massive continental glaciation, which formed an area of low relief broken by sounds, low moraine ridge systems, rounded hummocks, and lakes.

Subprovince code No.	Description
0401	Coastal plain
0402	Morainal features with islands
0403	Outwash plain
0404	Rolling moraine

Willamette Basin Province

This character type reflects a structural depression, modified visually by hills of low relief and alluvium deposited from ancient floods. The valley floor has a very gentle northerly slope, interspersed with sluggish, meandering streams.

Subprovince code No.	Description
0501	Flood plain—Recent (Willamette River and tributary)
0502	Lacustrine plains (agricultural lands)
0503	Foothills (Salem hills)
0504	Steep, short mountain slopes (Chehalem Mountain)

Western Cascades Province

This character type reflects a slightly folded and uplifted accumulation of weathered volcanic flows. The area is characterized by general conformity in ridge crests separated by deep valleys with steep, highly dissected slopes. Glacial features are evident but, being the result of less alpine glaciation, not as pronounced as found in the northwestern Cascades character. In the southern portion of the western Cascades, major valleys are V-shaped. Peaks over 7,000 feet are uncommon.

Subprovince code No.	Description
0601	Gorge
0602	Glaciated, steep, long mountain slopes (Salmon River)
0603	Foothills (Silver Falls)
0604	Steep, dissected mountain slopes (Bohemia)
0605	Steep, long mountain slopes (Rhododendron Ridge—Bull of the Woods)
0606	Steep, uneven mountain slopes (Dickey Creek)
0607	Rolling, plateau remnants (Bull Run country)

Northwestern Cascades Province

This character type is composed of sharp, jagged peaks and deep, steep-sloped valleys resulting mostly from alpine glaciation. A striking topographic feature is the approximately uniform elevation of the main ridgetops. Towering above these relatively even crests are two dormant volcanoes (Mount Baker and Glacier Peak) as well as several granitic peaks of exceptional height. Glacial features are common with literally hundreds of cirques; and some peaks ringed by cirques have been eroded to horns. Main stream valleys contain deep accumulations of glacial debris.

Subprovince code No.	Description
0701	Glacial valleys (Skagit River)
0702	Glaciated, steep, long mountain slopes with snow chutes
0703	Glaciated, steep, long mountain slopes—timbered
0704	Alpine and subalpine (Mount Baker) (peaks, meadow, etc.)

Northeastern Cascades Province

This character type is glacial sculpturing which has created an area of great relief with steep-sided, very deep valleys and long finger lakes. The area is made up of granitic batholiths, folded and in part metamorphosed, sedimentary rocks with ridgetops having approximately uniform crest elevations. The area reflects extensive glaciation, but cirques and horns are not as common as in the Northwestern Cascades character type.

Subprovince code No.	Description
0801	Glacial valleys (Cle Elum)
0802	Glaciated, steep, long mountain slopes with snow chutes (Stevens Pass)
0803	Glaciated, steep, long mountain slopes—timbered (Entiat)
0804	Alpine and subalpine (peaks, meadows, etc.)
0805	Plateau remnants (Table Mountain)
0806	Dissected mountain slopes (Mission Ridge)
0807	Tilted, dissected plateau land (Taneum)
0808	Finger lake (Lake Chelan)

Recent (High) Cascades Province

This character type consists of a volcanic plateau capped by shield volcanoes, cinder cones, and other volcanic forms, all of which are in various stages of dissection. It is essentially an area of gently sloping terrain interrupted at intervals by glaciated channels in the major drainages. The area is dotted with volcanic peaks and cones rising 150 to 5,000 feet above the surrounding landscape.

Subprovince code No.	Description
0901	Alpine and subalpine (Mount Hood)
0902	Plateau (Huckleberry Mountain)
0903	Glaciated, steep, long mountain slopes with snow chutes (northern half)
0904	Glaciated, steep, long mountain slopes
0905	Pumice-mantled outwash plain with craters and lakes (Cascade Lake Highway)

Okanogan Highlands Province

This character type reflects repeated continental glaciation, resulting in a generally rolling terrain of moderate slopes and broad, rounded summits. There is a scattering of peaks rising 3,000 to 4,000 feet above the general terrain, dividing the area into several upland areas separated by a series of broad north-south river valleys.

Subprovince code No.	Description
1001	Glaciated valleys (Methow)
1002	Plateaus (Omak Plateau)
1003	Glaciated, steep, long mountain slopes (Okanogan Range)
1004	Glaciated, rolling mountain slopes
1005	Low, rolling morainal features—grass covered
1006	Canyon lands (Columbia River)

Columbia Basin Province

This character type reflects the Columbia River basalt plateau which has been modified by glacial outwash floods and wind to form coulees, scablands, and rolling loess hills. Steep slopes are of limited occurrence and restricted to isolated basaltic buttes or canyons carved by some of the major rivers.

Subprovince code No.	Description
1101	Dissected basalt plateau land (Condon)
1102	Lacustrine plains (Quincy Basin)
1103	Coulees (Grand Coulee)
1104	Channeled scablands (Crab Creek)
1105	Rolling loess hills (Palouse)
1106	Outwash valleys (Yakima)
1107	Folded basalt ridges (Horse Heaven)
1108	Outwash plain (Waterville Plateau)
1109	Basalt plateau (Rattlesnake Ridge)
1110	Sand dunes (Richland)

Blue Mountains Province

This character type reflects several ranges of mountains separated by faulted valleys, synclinal (downfolded) basins, and lava plateaus. Topographic relief in the mountains is highly variable, with moderately steep slopes common.

Subprovince code No.	Description
1201	Dissected basalt and plateau land (Pendleton Ranger District)
1202	Lacustrine plains (Baker, Enterprise)
1203	Dissected basalt plateau land, grass covered (Imnaha)
1204	Steep, long mountain slopes (Dixie Mountain)
1205	Subalpine and alpine (Strawberry Mountain)
1206	Steep, short, dissected mountain slopes (Murderers Creek)
1207	Steep, short, highly dissected rolling lands (Vale)
1208	Dissected rhyolite plateau land-transition forest (Sagehen Hills)
1209	Badlands (Painted Hills)
1210	Lacustrine plain-high desert (Summit Prairie and Fox Basin)
1211	Canyon lands (Snake River)

Harney Basin Province

This character type reflects a young, relatively uniform expanse of lava flows of moderate relief in part mantled by pumice and ash falls and dotted with scattered cinder cones and lava buttes. Porous soil and bedrock and scanty rainfall cause many streams to be seasonal. Undrained basins containing shallow lakes, some dry and others with fluctuating levels, are common. Evidence of violent volcanic activity is abundant in the western portions, with the Paulina Peak shield volcano being the dominant feature. Outstanding examples of recent lava flows are near Lava Butte and Fort Rock.

Subprovince code No.	Description
1301	Rhyolite plateau land (Dog Mountain)
1302	Lacustrine basin-lakebeds (Harney Basin)
1303	Pumice-mantled, cinder cone, plateau land (Bend)
1304	Volcano-caldera (Newberry)
1305	Recent basalt flow (Lava Butte)
1306	Pumice-mantled plateau land (Fort Rock)

Upper Basin and Range Province

This character type reflects fault block mountains enclosing basins with internal drainage at generally higher elevations than the main Basin and Range Province. These formations create predominantly horizontal profiles in mountain silhouette with occasional cone-shaped features. Precipitation is moderate, coming mostly as snow; most streams are perennial; and numerous undrained basins contain shallow lakes and marshes.

Subprovince code No.	Description
1401	Fault block mountains (Yainax Butte)
1402	Graben valleys
1403	Rolling sagebrush lands (Bly Ranger District)
1404	Dissected plateau lands (Paisley Ranger District)
1405	Lacustrine basin-marshes (Klamath)
1406	Pumice-mantled rolling hills—high elevation (Antelope Flats)
1407	Alpine and subalpine (Yamsay Mountain)

Basin and Range Province

This character type reflects fault block mountains enclosing basins with internal drainage. These formations create predominantly horizontal profiles in mountain silhouette. Except for slopes of the fault block mountains, the area is rolling with low relief. Rainfall is scanty, most streams are intermittent, and numerous undrained basins contain shallow, saline lakes.

Subprovince code No.	Description
1501	Alpine and subalpine (Steens Mountain)
1502	Lacustrine basin-lake beds
1503	Active sand dunes
1504	Canyon lands (Owyhee)
1505	Fault block mountain (Hart Mountain)
1506	Graben valleys (Alvord Desert)
1507	Rolling sagebrush land, low relief
1508	Pumice-mantled plateau land (Chemult)

Cowlitz River Basin Province

This character type reflects a structural depression occupied by the lower and middle Cowlitz River. Uplands of rolling hills of low relief composed of volcanic geologic materials are the dominant terrain feature. Lacustrine plains, terraces, and flood plains adjacent to the rivers occupy proportionately less area than in the Willamette Basin Province. The area has an overall southerly slope.

Subprovince code No.	Description
1601	Flood plain
1602	Outwash plain
1603	Foothills
1604	Steep, short mountain slopes

Wallowas Province

This character type reflects a mountainous "island" surrounded by lava plateaus. These mountains are part of the Blue Mountains Province but are distinctive, as alpine glaciation has created a very precipitous and rugged mountainous area. Cirques, glacial lakes, and moraines are common. The relief in the Wallowas is much greater than in the Blue Mountains type.

Subprovince code No.	Description
1701	Alpine and subalpine
1702	Basalt plateau (Tamarack Flat)
1703	Dissected basalt plateau (Minam)
1704	Glaciated, steep, long mountain slopes

APPENDIX VI.

LISTS OF VERTEBRATE ANIMALS OF SPECIAL INTEREST IN WASHINGTON AND OREGON

These inventories of animals considered to be of special interest are aimed at calling attention to them. Only those species marked with an asterisk were included in rare and endangered cells, as they were considered to be compatible with protection in Research Natural Areas. The animals listed represent a fragile segment of our biological heritage and, as such, merit our constant surveillance and stewardship.

Vertebrate animals in the following lists which also appear in the 1973 edition of "Threatened Wildlife of the United States" (Red Book) (U.S. Bureau of Sport Fisheries and Wildlife) are so indicated.

The vertebrate animal species which appear in the following lists may be in one of a number of different categories defined in the report of the Rare and Endangered Species Working Group. These categories include rare, uncommon, endangered, threatened, peripheral, unique, and status undetermined. Since these criteria have been used thus far solely for the classification of mammals of special interest in Oregon and Washington, they are the only lists in which status is indicated for each species.

Mammal species identified as "threatened" or "endangered" in these lists are according to the criteria laid down in "Report of Rare and Endangered Species Working Group" (pt. IV) and carry no *official* status. The only species having legal status as threatened or endangered are those so designated by the Secretary of the Interior according to the provisions of the Endangered Species Act of 1973.

Fishes of Special Interest in Washington[1]

**Novumbra hubbsi*, Olympic mudminnow
Rhinichthys falcatus, leopard dace
Percopsis transmontana, sand roller
Gasterosteus aculeatus microcephalus, black stickleback

Fishes of Special Interest in Oregon[2]

Lampetra ayresi, river lamprey
Lampetra richardsoni, Western brook lamprey
Lampetra lethophaga, Pit-Klamath brook lamprey
Salmo clarki subsp., Alvord cutthroat trout
Salmo sp., redband trout
Salvelinus malma, Klamath Basin representative of Dolly Varden
Gila bicolor subsp., catlow tui chub
Gila alvordensis, Alvord chub
**Hesperoleucus symmetricus*, California roach

[1] Richard S. Wydoski compiled this list in 1973; it was sent to us by Dick Whitney, University of Washington, in 1974.

[2] Carl E. Bond, Oregon State University, updated this list in 1974.

*Animal has been identified as a rare and endangered cell.

Hybopsis crameri, Oregon chub
Rhinichthys cataractae subsp., Millicoma dace
Rhinichthys osculus subsp., Fosket Spring dace
Rhinichthys falcatus, leopard dace
**Richardsonius egregius*, Lahontan redside
Catostomus luxatus, Lost River sucker
Catostomus (*rimiculus* subsp. ?), Jenny Creek sucker
**Catostomus tahoensis*, Tahoe sucker
Catostomus warnerensis, Warner sucker
Chasmistes brevirostris, shortnose sucker
Percopsis transmontana, sand roller
**Cottus bairdi* subsp., Malheur sculpin
Cottus princeps, Klamath Lake sculpin

Reptiles and Amphibians of Special Interest in Washington[3]

**Plethodon dunni*, Dunn salamander
**Plethodon larselli*, Larch Mountain salamander
**Bufo woodhousei*, Woodhouse toad
Rana clamitans, green frog
**Clemmys marmorata*, western pond turtle
**Gerrhonotus multicarinatus scincicauda*, Oregon alligator lizard
**Diadophis punctatus amabilis*, Pacific ringnecked snake
**Contia tenuis*, sharp-tailed snake
**Masticophis taeniatus*, striped whipsnake
**Lampropeltis zonata*, California mountain kingsnake
**Hypsiglena torquata*, night snake

Reptiles and Amphibians of Special Interest in Oregon[4]

**Plethodon larselli*, Larch Mountain salamander
**Plethodon elongatus*, Del Norte salamander
**Plethodon stormi*, Siskiyou Mountain salamander
**Plethodon gordoni*, Marys Peak salamander
**Batrachoseps wrighti*, Oregon slender salamander
**Batrachoseps attenuatus*, California slender salamander
**Aneides flavipunctatus*, black salamander
**Ascaphus truei*, tailed frog
**Rana pretiosa*, spotted frog
Crotaphytus collaris, collared lizard
Crotaphytus wislizeni, leopard lizard
Phrynosoma platyrhinos, desert horned lizard
Cnemidophorus tigris, Western whiptail
**Contia tenuis*, sharp-tailed snake
**Lampropeltis getulus*, common kingsnake
**Lampropeltis zonata*, California mountain kingsnake
**Crotalus viridis*, Western rattlesnake

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[3] Murray L. Johnson, University of Puget Sound, prepared this list in 1974.
[4] Robert M. Storm, Oregon State University, updated this list in 1974.
*Animal has been identified as a rare and endangered cell.

Birds of Special Interest in Washington[5] [6]

Diomedea cauta cauta, Tasmanian white-capped albatross
Puffinus carneipes, pale-footed shearwater
Puffinus bulleri, New Zealand shearwater
Puffinus puffinus opisthomelas, black-vented shearwater
Phaeton aethereus mesonauta, Northern red-billed tropic-bird
Pelecanus erythrorhynchos, white pelican
Pelecanus occidentalis californicus, California brown pelican[7]
Sula nebouxii nebouxii, Northern blue-footed booby
Butorides virescens anthonyi, Anthony's green heron
Bulbucus ibis ibis, cattle egret
Casmerodius albus egretta, common egret
Leucophoyx thula brewsteri, Brewster's snowy egret
Botaurus lentiginosus, American bittern
Plegadis chihi, white-faced ibis
Olor buccinator, trumpeter swan
Branta canadensis leucopareia, Aleutian Canada goose[7]
Branta canadensis parvipes, lesser Canada goose
Branta bernicla hrota, American brant
Philacte canagica, emperor goose
Dendrocygna bicolor helva, Northern fulvous tree duck
Anas rubripes, black duck
Anas penelope, European widgeon
Somateria mollissima nigra, Pacific common eider
Somateria spectabilis, king eider
Melanitta deglandi deglandi, white-winged scoter
Cathartes aura teter, turkey vulture
Gymnogyps californianus, California condor
Buteo jamaicensis alascensis, Alaska red-tailed hawk
Buteo lagopus johannis, American rough-legged hawk
Buteo regalis, ferruginous hawk
Aquila chrysaetos canadensis, golden eagle
Haliaeetus leucocephalus alascanus, Northern bald eagle
Pandion haliaetus carolinensis, American osprey
Caracara cheriway audubonii, caracara
Falco rusticolus obsoletus, gyrfalcon
Falco rusticolus uralensis, Asiatic gyrfalcon
Falco mexicanus, prairie falcon
Falco peregrinus anatum, American peregrine falcon
Falco peregrinus pealei, Peale's falcon
Falco columbarius suckleyi, black pigeon hawk
Falco columbarius bendirei, Western pigeon hawk
Falco sparverius sparverius, Western sparrow hawk
Dendragapus obscurus richardsonii, Richardson's blue grouse
Pediocetes phasianellus columbianus, Columbian sharp-tailed grouse
Centrocercus urophasianus phaios, Western sage grouse
Rallus limicola limicola, Virginia rail
Coturnicops noveboracensis noveboracensis, yellow rail
Eupoda montana, mountain plover

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[5] Because of their wide-ranging habit, only two species have been given natural area cell status.
[6] Gordon D. Alcorn, University of Puget Sound, updated this list in 1974.
[7] Species is on national list of threatened and endangered animals (U.S. Bureau of Sport Fisheries and Wildlife 1973).

Eudromias morinellus, dotterel
Numenius americanus parvus, long-billed curlew
Bartramia longicauda, upland plover
Tringa solitaria solitaria, solitary sandpiper
Catoptrophorus semipalmatus inornatus, western willet
Calidris canutus canutus, Pacific knot
Calidris canutus rufa, American knot
Calidris acuminata, sharp-tailed sandpiper
Calidris fuscicollis, white-rumped sandpiper
Calidris bairdii, Baird's sandpiper
Calidris pusilla; semipalmated sandpiper
Tryngites subruficollis, buff-breasted sandpiper
Limosa fedoa, marbled godwit
Limosa haemastica, Hudsonian godwit
Himantopus mexicanus, black-necked stilt
Stercorarius pomarinus, pomarine jaeger
Stercorarius longicaudus, long-tailed jaeger
Catharacta skua antarctica, Falkland skua
Catharacta skua lonnbergi, brown skua
Larus hyperboreus barrovianus, glaucous gull
Larus glaucoides glaucoides, Iceland gull
Larus pipixcan, Franklin's gull
Sterna paradisaea, Arctic tern
Hydroprogne caspia, Caspian tern
Endomychura hypoleuca scrippsi, Xantus' murrelet
Fratercula corniculata, horned puffin
Bybo virginianus wapacuthu, Arctic horned owl
Nyctea scandiaca, snowy owl
Surnia ulula caparoch, American hawk-owl
**Speotyto cunicularia hypugaea*, Western burrowing owl
Strix varia, barred owl
Strix nebulosa nebulosa, great gray owl
Aegolius funereus richardsoni, boreal owl
Eremophila alpestris strigata, streaked horned lark
Aphelocoma coerulescens immanis, Oregon scrub jay
**Parus hudsonicus cascadensis*, Cascade boreal chickadee
Parus rufescens rufescens, chestnut-backed chickadee
Psaltriparus minimus minimus, coast bushtit
Sitta canadensis, red-breasted nuthatch
Certhia familiaris occidentalis, tawny brown creeper
Chamaea fasciata phaea, wrentit
Telmatodytes palustris paludicola, Tule wren
Catharus guttata polionta, white mountain hermit thrush
Sialia mexicana occidentalis, Western bluebird
Regulus satrapa olivaceus, Western golden-crowned kinglet
Regulus calendula grinnelli, Sitka kinglet
Acridotheres cristatellus cristatellus, crested myna
Vireo huttoni huttoni, Hutton's vireo
Vireo solitarius cassinii, Cassin's vireo
Vireo olivaceus, red-eyed vireo
Vireo gilvus swainsonii, Western warbling vireo
Mniotilta varia, black-and-white warbler
Vermivora peregrina, Tennessee warbler

*Animal has been identified as a rare and endangered cell.

Vermivora celata celata, orange-crowned warbler
Vermivora celata lutescens, lutescent warbler
Dendroica coronata coronata, myrtle warbler
Dendroica coronata auduboni, Audubon's warbler
Dendroica coronata memorabilis, Western Audubon's warbler
Dendroica nigrescens, black-throated gray warbler
Seiurus noveboracensis notabilis, Northern waterthrush
Oporornis tolmiei tolmiei, McGillivray's warbler
Geothlypis trichas campicola, Western yellowthroat
Geothlypis trichas arizela, Pacific yellowthroat
Setophaga ruticilla tricolora, North American redstart
Sturnella neglecta confluenta, Western meadowlark
Passerina amoena, Lazuli bunting
Pinicola enucleator alascensis, Alaska pine grosbeak
Pinicola enucleator flammula, Kodiak pine grosbeak
Leucosticte tephrocotis tephrocotis, Swainson's gray-crowned rosy finch
Pooecetes aramineus affinis, Oregon vesper sparrow
Junco hyemalis cismontanus, Cassiar slate-colored junco
Junco hyemalis montanus, interior slate-colored Oregon junco
Spizella arborea ochracea, tree sparrow
Zonotrichia querula, Harris' sparrow
Passerella iliaca zaboria, Yukon fox sparrow
Melospiza melodia montana, mountain song sparrow
Melospiza melodia kenaiensis, Kenai song sparrow
Melospiza melodia caurina, Yakutat song sparrow

Birds of Special Interest in Oregon[8] [9]

Podiceps grisegena holbollii, Holboell's red-necked grebe
Podiceps auritus, horned grebe
Oceanodroma furcata plumbea, Southern fork-tailed petrel
Pelecanus erythrorhynchos, white pelican
Pelecanus occidentalis californicus, California brown pelican[10]
Casmerodius albus egretta, common egret
Leucophoyx thula brewsteri, Brewster's snowy egret
Ixobrychus exilis hesperis, Western least bittern
Plegadis chihi, white-faced ibis
Olor buccinator, trumpeter swan
Branta canadensis leucopareia, Aleutian Canada goose[10]
Anser albifrons gambelli, Tule white-fronted goose
Aythya collaris, ring-necked duck
Aythya affinis, lesser scaup
Bucephala islandica, Barrow's goldeneye
Bucephala albeola, bufflehead
Histrionicus histrionicus, harlequin duck
Buteo swainsoni, Swainson's hawk
Buteo regalis, ferruginous hawk
Haliaeetus leucocephalus alascanus, Northern bald eagle
Pandion haliaetus carolinensis, American osprey
Falco mexicanus, prairie falcon
Falco peregrinus anatum, American peregrine falcon[10]

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[8] Because of their wide-ranging habit, only two species have been given natural area cell status.
[9] David B. Marshall, U.S. Fish and Wildlife Service, prepared this list in 1969.
[10] Species is on national list of threatened and endangered animals (U.S. Bureau of Sport Fisheries and Wildlife 1973).

Falco columbarius bendirei, Western pigeon hawk
Dendragapus obscurius sierrae, Sierra blue grouse
Canachites canadensis franklinii, Franklin's spruce grouse
Pedioecetes phasianellus columbianus, Columbian sharp-tailed grouse
Grus canadensis tabida, greater sandhill crane
Coturnicops noveboracensis noveboracensis, yellow rail
Charadrius alexandrinus nivosus, Western snowy plover
Bartramia longicauda, upland plover
Limnodromus griseus caurinus, Alaskan short-billed dowitcher
Himantopus mexicanus, Black-necked stilt
Larus pipixcan, Franklin's gull
Hydroprogne caspia, Caspian tern
Brachyramphus marmoratum marmoratum, American marbled murrelet
Cerorhinca monocerata, rhinoceros auklet
Coccyzus americanus occidentalis, California yellow-billed cuckoo
Otus asio bendirei, California screech owl
Otus flammeolus, flammulated owl
Glaucidium gnoma californicum, California pygmy owl
**Strix occidentalis caurina*, Northern spotted owl
Strix nebulosa nebulosa, great gray owl
**Speotyto cunicularia hypugaea*, Western burrowing owl
Phalaenoptilus nuttallii californicus, dusky poor-will
Selasphorus sasin, Allen's hummingbird
Picoides tridactylus fasciatus, Alaska Northern three-toed woodpecker
Sayornis phoebe, Eastern phoebe
Sayornis nigricans semiatra, black phoebe
Progne subis subis, Northern purple martin
Aphelocoma coerulescens nevadae, Nevada scrub jay
Aphelocoma coerulescens oocleptica, Nicasio scrub jay
Parus inornatus zaleptus, Warner Valley titmouse
Thryomanes bewickii atrestus, Warner Valley Bewick's wren
Mimus polyglottos leucopterus, Western mockingbird
Dumetella carolinensis, catbird
Hylocichla fuscescens salicicola, willow veery
Polioptila caerulea amoenissima, Western blue-gray gnatcatcher
Anthus spinoletta pacificus, Western water pipit
Bombycilla garrula pallidiceps, Bohemian waxwing
Vireo huttoni huttoni, Hutton's vireo
Setophaga ruticilla tricolora, North American redstart
Dolichonyx oryzivorus, bobolink
Agelaius tricolor, tricolored blackbird
Pinicola enucleator montana, Rocky Mountain pine grosbeak
Leucosticte tephrocotis wallowa, Wallowa gray-crowned rosy finch
Leucosticte atrata, black rosy finch
Ammodramus savannarum perpallidus, Western grasshopper sparrow
Amphispiza bilineata deserticola, desert black-throated sparrow

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*Animal has been identified as a rare and endangered cell.

Mammals of Special Interest in Washington[11]

Didelphis virginiana, Virginia opossum (introduced), Uncommon
**Sorex cinereus hollisteri*, masked shrew, Rare
**Sorex cinereus cinereus*, masked shrew, Uncommon
**Sorex preblei*, Malheur or Preble shrew, Rare
**Sorex merriami*, Merriam shrew, Rare
**Microsorex hoyi*, pygmy shrew, Rare
Myotis keeni, Keen bat, Rare
Myotis evotis, long-eared bat, Uncommon
Myotis thysanodes, fringed bat, Rare
Myotis volans, long-legged bat, Rare
Myotis leibii, small-footed bat, Rare
Lasionycteris noctivagans, silver-haired bat, Rare
Lasiurus cinereus, hoary bat, Rare
Antrozous pallidus, pallid bat, Rare
**Sylvilagus idahoensis*, pygmy rabbit, Threatened
**Lepus townsendi*, white-tailed jack rabbit, Uncommon
**Spermophilus washingtoni*, Washington ground squirrel, Uncommon
**Sciurus griseus*, Western gray squirrel, Uncommon
Sciurus niger, fox squirrel (introduced), Uncommon
Thomomys talpoides limosus, Northern pocket gopher, Uncommon
Thomomys talpoides douglasi, Northern pocket gopher, Threatened
Thomomys mazama couchi, Western pocket gopher, Rare
Thomomys mazama glacialis, Western pocket gopher, Rare
Thomomys mazama louiei, Western pocket gopher, Rare
**Thomomys mazama melanops*, Western pocket gopher, Rare
Thomomys mazama tacomensis, Western pocket gopher, Endangered
Thomomys mazama tumuli, Western pocket gopher, Rare
**Dipodomys ordi*, Ord kangaroo rat, Rare
**Onychomys leucogaster*, Northern grasshopper mouse, Rare
**Phenacomys intermedius*, heather vole, Uncommon
**Microtus pennsylvanicus kinkaid*, Kinkaid meadow vole, Uncommon
Microtus canicaudus, gray-tailed vole, Rare
**Lagurus curtatus*, sagebrush vole, Uncommon
**Synaptomys borealis*, Northern bog lemming, Rare
Mesoplodon carlhubbsi, Moore beaked whale, Rare
Stenella caeruleoalba, striped porpoise, Uncommon
Lissodelphis borealis, Northern right-whale dolphin, Uncommon
Lagenorhynchus obliquidens, Pacific white-sided dolphin, Uncommon
Grampus griseus, grampus, Uncommon
Pseudorca crassidens, false killer whale, Uncommon
Globicephala macrorhyncha, short-finned pilot whale, Uncommon
Balaenoptera acutorostrata, little piked whale, Uncommon
Balaenoptera musculus, blue whale, Rare
Balaena glacialis, right whale, Uncommon
Canis lupus, gray wolf, Extinct
Vulpes vulpes macroura, red fox, Rare

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[11] Murray L. Johnson, University of Puget Sound, compiled this list in 1974. Status of mammal is according to his classification system (see pt. IV).

*Animal has been identified as a rare and endangered cell.

Ursus arctos, grizzly bear, Threatened
Martes pennanti, fisher, Uncommon
Gulo gulo, wolverine, Rare
Enhydra lutris, sea otter (reintroduced), Rare
Lynx lynx, lynx, Rare
Zalophus californianus, California sea lion, Uncommon
Mirounga angustirostris, Northern elephant seal, Rare
Odocoileus virginianus leucurus, Columbia white-tailed deer, Endangered[12]
Alces alces, American moose, Uncommon
Rangifer tarandus, caribou, Threatened
Antilocapra americana, pronghorn (reintroduced), Rare
Bison bison, bison, Extinct
Ovis canadensis, mountain sheep (reintroduced), Uncommon

Mammals of Special Interest in Oregon[13]

**Sorex preblei*, Malheur or Preble shrew, Rare
**Sorex trigonirostris*, Ashland shrew, Rare
**Sorex merriami*, Merriam shrew, Rare
Myotis evotis, long-eared bat, Uncommon
Myotis thysanodes, fringed bat, Rare
Myotis volans, long-legged bat, Rare
Myotis leibii, small-footed bat, Rare
Lasionycteris noctivagans, silver-haired bat, Rare
Pipistrellus hesperus, Western pipistrelle, Rare
Lasiurus cinereus, hoary bat, Rare
Antrozous pallidus, pallid bat, Rare
Tadarida brasiliensis, Brazilian free-tailed bat, Rare
**Sylvilagus idahoensis*, pygmy rabbit, Uncommon
**Lepus townsendi*, white-tailed jack rabbit, Uncommon
**Spermophilus washingtoni*, Washington ground squirrel, Threatened
**Spermophilus richardsoni*, Richardson ground squirrel, Rare
Sciurus carolinensis, Eastern gray squirrel (introduced), Uncommon
Sciurus niger, fox squirrel (introduced), Rare
**Thomomys bottae detumidus*, Botta pocket gopher, Rare
**Thomomys bottae laticeps*, Botta pocket gopher, Rare
**Perognathus longimembris*, little pocket mouse, Rare
**Peromyscus truei sequoiensis*, pinon mouse, Uncommon
**Peromyscus truei preblei*, pinon mouse, Uncommon
**Onychomys leucogaster*, Northern grasshopper mouse, Uncommon
**Phenacomys intermedius*, heather vole, Uncommon
**Arborimus albipes*, white-footed vole, Rare
**Arborimus longicaudus longicaudus*, red tree vole, Uncommon
**Arborimus longicaudus silvicola*, red tree vole, Uncommon
**Lagurus curtatus*, sagebrush vole, Uncommon
Mesoplodon carlhubbsi, Moore beaked whale, Rare
Stenella caeruleoalba, striped porpoise, Uncommon

---

[12] Species is on national list of threatened and endangered animals (U.S. Bureau of Sport Fisheries and Wildlife 1973).

[13] Murray L. Johnson and Chris Maser, University of Puget Sound, compiled this list in 1974. Status of mammal is according to Johnson's classification system (see pt. IV).

*Animal has been identified as a rare and endangered cell.

Lissodelphis borealis, Northern right-whale dolphin, Uncommon
Lagenorhynchus obliquidens, Pacific white-sided dolphin, Uncommon
Grampus griseus, grampus, Uncommon
Pseudorca crassidens, false killer whale, Uncommon
Globicephala macrorhyncha, short-finned pilot whale, Uncommon
Balaenoptera acutorostrata, little piked whale, Uncommon
Balaenoptera musculus, blue whale, Rare
Canis lupus, gray wolf, Extinct
Vulpes vulpes cascadensis, red fox, Uncommon
Vulpes vulpes macroura, red fox, Rare
Vulpes macrotis, kit fox, Threatened
Ursus arctos, grizzly bear, Extinct
Bassariscus astutus, ringtail, Rare
Martes pennanti, fisher, Rare
Gulo gulo, wolverine, Threatened
Enhydra lutris, sea otter (reintroduced), Uncommon
Lynx lynx, lynx, Extinct
Callorhinus ursinus, Northern fur seal, Uncommon
Eumetopias jubata, Northern sea lion, Uncommon
Phoca vitulina, harbor seal, Rare
Mirounga angustirostris, Northern elephant seal, Rare
Odocoileus virginianus leucurus, Columbia white-tailed deer, Rare[14]
Odocoileus virginianus ochrourus, white-tailed deer, Rare
Antilocapra americana, pronghorn, Uncommon
Bison bison, bison, Extinct
Oreamnos americanus, mountain goat (introduced), Rare
Ovis canadensis, mountain sheep (reintroduced), Rare

[14] Species is on national list of threatened and endangered animals (U.S. Bureau of Sport Fisheries and Wildlife 1973).

APPENDIX VII.
LIST OF WORKSHOP PARTICIPANTS

Workshop Chairman

Jerry F. Franklin, Program Director, Ecosystem Studies, National Science Foundation, 1800 G. Street, N.W., Washington, D.C. 20550.

Steering Committee

Chairman: Robert E. Buckman, Director, Pacific Northwest Forest and Range Experiment Station, P.O. Box 3141, Portland, Oreg. 97208.

Archie D. Craft, State Director, represented by Irving W. Anderson, Chief, Branch of Land & Mineral Operations, U.S. Bureau of Land Management, P.O. Box 2965, Portland, Oreg. 97208.

Don Lee Fraser, Supervisor, Department of Natural Resources, represented by Howard Stolaas, Deputy Supervisor, Department of Natural Resources, State of Washington, Olympia, Wash. 98504.

A. R. Kruckeberg, Professor and Chairman, Department of Botany, University of Washington, Seattle, Wash. 98195.

Kenneth R. Margolis, Northwest Representative, The Nature Conservancy, 1234 N.W. 25th Ave., Portland, Oreg. 97210.

R. Kahler Martinson, Regional Director, U.S. Fish and Wildlife Service, P.O. Box 3737, Portland, Oreg. 97208.

John A. Rutter, Regional Director, National Park Service, 523 4th and Pike Bldg., Seattle, Wash. 98101.

Theodore A. Schlapfer, Regional Forester, U.S. Forest Service, Region 6, P.O. Box 3623, Portland, Oreg. 97208.

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Al M. Wiedemann, Biology Department, Evergreen State College, Olympia, Wash. 98501.

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Curt Wiberg, Biology Department, Central Washington State College, Ellensburg, Wash. 98926.

Marine and Estuarine Working Group

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Al R. O'Donnell, Supervisor, Recreation Division, Department of Natural Resources, State of Washington, Olympia, Wash. 98504.

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1975
USDA FOREST SERVICE GENERAL TECHNICAL REPORT PNW-39

FOREST RESIDUES in Hemlock-Spruce Forests of the Pacific Northwest and Alaska--

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A State-of-Knowledge Review with Recommendations for Residue Management

Robert H. Ruth
A. S. Harris

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
PORTLAND, OREGON

SUMMARY

The forest manager must balance all the interacting and often conflicting factors influencing residue management and decide on the best course of action. He needs to determine optimum volume, size, and arrangement of residues to leave on an area after logging, then to select the harvesting methods and residue management alternatives that best provide these conditions. Cramer (1974) summarized environmental effects of forest residues management for major forest types in the Pacific Northwest, but types of treatment were not listed and only minor attention was given to hemlock-spruce forests. Residue management guidelines have been prepared for Oregon and Washington (Pierovich et al. 1975) but the hemlock-spruce type is not discussed as a separate entity. Alaska is not included in either report. This report provides a detailed look at residue management throughout the north Pacific coastal fog belt, including Oregon, Washington, British Columbia, and Alaska. The approach is a general look at forest residues as part of the ecosystem, then a closer look at dead and decaying material after logging, considering fire hazard and the silvicultural, physical, chemical, and esthetic effects of this material. Residue treatments are described, evaluated, and recommended. The report is intended to provide an improved scientific framework for management decisions.

The coastal environment is more moist than other parts of the Pacific Northwest. Generally, fire danger is low and the need for residue treatment to reduce fire hazard is limited to special situations. Northward into Alaska, increasing summer precipitation relegates fire danger to a subordinate management problem.

Hemlock-spruce residue volumes may range up to 250 tons per acre (560 metric tons per hectare) when an old-growth timber stand is defective and has a high proportion of western redcedar, but volumes may be less than 50 tons per acre (112 metric tons per ha) with more complete utilization of sound young timber. The trend is to less residue volume as defective timber is replaced by vigorous young stands and utilization improves.

Residues often dominate the postlogging environment and are a major factor influencing forest regeneration. Fresh residue intercepts natural seed fall or aerially sown seed and prevents seedling establishment; but later, as it decays and with moisture present, it becomes a suitable seed bed for hemlock and spruce. Advance regeneration, usually hemlock, grows on decaying residue material and almost invariably is intermixed with fresh logging residue. Its fate is determined by residue treatment. When residue treatments expose mineral soil, they influence species composition favoring seral species. These ecological relationships between forest residues and conifer seedlings can be used by forest managers to influence density and species composition of the new timber stand. A common problem in hemlock-spruce is too many seedlings. When advance regeneration is prolific, harvesting plans and residue treatments should be designed to destroy some of the seedlings. Overstocking with postlogging regeneration can be reduced if the logging operation is planned so that fresh slash covers an appropriate portion of suitable seed beds.

In special situations, individual factors carry heavy weight in residue management decisions. For soils with high erosion potential, a protective mantle of organic material should be left. At least the small residue material should be left on nutrient-deficient soils to add to the nutrient capital. Residue should be kept out of stream channels. In Oregon and Washington, broadcast burning of residues in heavy brush areas helps to control the brush and open up the area for planting. Mistletoe-infested seedlings should be classed as residue and destroyed as part of disease control programs. Special attention should be given to residue management in recreation and scenic areas. Large, continuous areas of logging slash should be avoided because of fire hazard. Smoke management plans should be followed. Treatments are needed when residue volume is too great, because the residue will interfere with seedling establishment and intensive management of the new stand.

KEYWORDS: Forest residues, western hemlock, Sitka spruce, slash disposal.

CONTENTS

INTRODUCTION

The unmerchantable organic material remaining after a forest is logged is a challenge to the forest manager. Depending on circumstances, forest residues are a fire hazard endangering the forest, an obstruction to intensive management, a blight on the landscape, a suitable seed bed for tree seedlings or an obstruction to their establishment, a source of essential nutrients, and a protective cover preventing soil erosion. Usually, they are a combination of all these and more. The challenge is for the forest manager to balance all the factors by determining the optimum volume, size, and arrangement of residues that should be left on an area after logging, and by selecting the harvesting methods and residues management alternatives that best provide these conditions. This should be done before harvest cutting because residue treatment begins with transportation planning and selection of the harvesting method and equipment.

Knowledge of the various environmental effects of forest residues and their treatments was summarized for primary forest types of the Pacific Northwest in a compendium (Cramer 1974). That document provides a background for understanding environmental effects of residues, but management practices are not listed. It gives only minor attention to western hemlock-Sitka spruce (*Tsuga heterophylla-Picea sitchensis*) forests. Residue management guidelines have been prepared for Oregon and Washington (Pierovich et al. 1975) but the hemlock-spruce type is not discussed as a separate entity. Neither of these reports include Alaska. This report provides a more detailed look at the coastal forests where the environment is much more moist than in other parts of the Pacific Northwest. Generally, fire danger is low, and an overriding need for disposal of residue to reduce fire hazard, so common farther inland, is limited to special situations. Northward into Alaska, increasing summer precipitation relegates fire danger to a subordinate position in residue management.

Historically, the approach to residue management in hemlock-spruce forests of Oregon and Washington has been to utilize logs that turned a profit, leaving all other logs and organic material to decay on the site. Continuous clearcutting left continuous logging slash. When wildfire started, it spread rapidly. This fire problem led to broadcast burning prescriptions to reduce the hazard and also led to restrictions on clearcut size. After World War II, many owners adopted the patch-cutting system, in which clearcuts are kept small and green timber left around the perimeter until logging residues are treated or the fire hazard has abated. In British Columbia, there has been a parallel trend to restrict clearcut size and broadcast burn high hazard areas, also a trend to leave uncut strips of green timber as firebreaks. In Alaska, until recently, clearcutting of large areas was the rule. Now clearcut size is restricted, mainly for esthetic reasons. Logging residues are left unburned.

Residue management is fast becoming recognized as an essential part of overall management that affects not only fire hazard but regeneration, site productivity, esthetics, future stand management, and many other factors (Cramer 1974). It should be fully integrated into general management planning.

Several methods for controlling the amount, composition, and distribution of hemlock-spruce logging residues are available. These include selection of yarding methods and equipment, utilization standards, yarding unutilized material (YUM), lopping and scattering of residues, broadcast burning, piling and burning, burning concentrations, and chipping. Armed with these techniques and new ones being developed, forest managers should be able to select the most desirable

postlogging condition for a cutover area and to achieve this through careful advance planning and application of residue treatments. This report is intended to provide a background for achieving this goal.

Residue management recommendations made here have the basic objectives of protecting the soil and its nutrient capital, streamflow, and water quality and of providing for establishment of a new forest crop. The land manager must evaluate residue management alternatives, considering economic, esthetic, and recreational objectives, and choose the most appropriate course of action.

HEMLOCK-SPRUCE FORESTS

Hemlock-spruce forests occupy a 2,000-mile-long (3200-kilometer) coastal strip from northern California to Prince William Sound, Alaska. This north Pacific coastal area provides some of the best forest growing conditions on the North American continent.

Including coastal islands, the hemlock-spruce type is about 130 miles (210 km) wide in Alaska, gradually narrowing southward until in California it becomes restricted to the mouths of coastal streams and low valleys facing the ocean (fig. 1). The climate is characterized by equable temperatures, heavy precipitation, and prolonged cloudiness. Its marine climate is greatly influenced by the warm ocean currents of the north Pacific and the prevailing onshore winds which carry their effects to the lands. In the south, infrequent summer rains are augmented by fog drip in established forests and by decreased evaporation in the frequently foggy and cool climate. The summer drought, so characteristic inland in the Pacific Northwest, is not pronounced in hemlock-spruce forests. But occasional rainless periods of 1 to several weeks may occur, usually in July or August, during which severe fire danger exists. Northward into Alaska, periods of drought are uncommon, but they occur often enough that fire danger cannot be completely discounted in making residue management decisions.

In the southern portion of the range there's a rapid, almost abrupt increase in fire danger inland from the beach. This coincides with reduced summer fog and transition in timber type, usually from hemlock-spruce to hemlock, to hemlock and Douglas-fir (*Pseudotsuga menziesii*), to Douglas-fir. In Alaska, this transition to drier interior conditions is well defined because along most of the Alaskan coast, icefields, glaciers, and low timberlines provide abrupt limits to the hemlock-spruce type. Except for the Kenai Peninsula, the head of Lynn Canal, and some of the larger rivers, a gradual transition in forest type from wet coastal forests to the drier interior forests is lacking.

Residue management recommendations presented here apply to fog belt forests of hemlock-spruce. These forests vary from pure hemlock to pure spruce, including mixtures and occasional pure stands of associated western redcedar, red alder, or Pacific silver fir. Associated species vary by latitude. Toward the south, they include redwood (*Sequoia sempervirens*), Douglas-fir, Port-Orford-cedar (*Chamaecyparis lawsoniana*), and other species. Toward the north and west, Alaska-cedar (*Chamaecyparis nootkatensis*) and mountain hemlock (*Tsuga mertensiana*) become important associates. The hemlock-spruce forest type is the dominant coastal vegetation in all of southeast Alaska, Washington, and Oregon (fig. 1).

Toward the south, extensive even-aged stands predominate; most have become established following great fires 80 to 100 years ago. Less extensive old-growth, uneven-aged stands are found also, most notably on the Olympic Peninsula

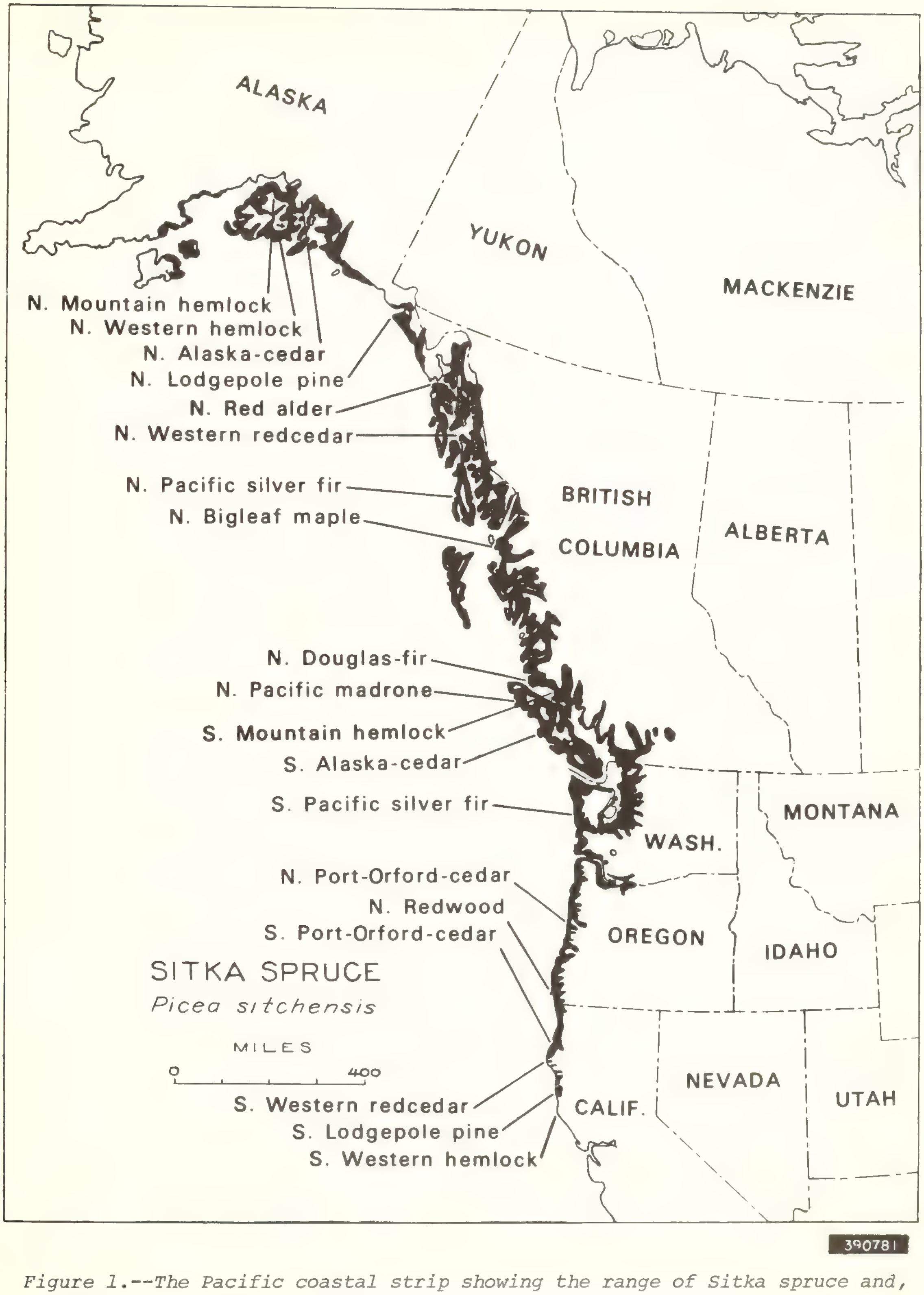

Figure 1.--The Pacific coastal strip showing the range of Sitka spruce and, within it, the approximate range of associated tree species. N and S indicate approximate north and south limits of range at sea level.

of Washington. In Alaska this pattern is reversed, with old-growth, uneven-aged stands predominating but interspersed with even-aged stands, mostly 100 to 250 years of age, which owe their origin to fire or blowdown.

These coastal forests are well located for and adapted to providing a variety of important public benefits. They have high esthetic and recreation values. Timber yields also are high, and there are excellent opportunities for increases through intensive management. The forest cover prevents soil erosion in coastal watersheds, protects domestic water supplies and important fish habitats, and provides habitat for wildlife. Demands for all of these forest benefits are increasing, and questions of residue management must be examined in this context.

FOREST RESIDUES--WHAT ARE THEY?

Viewed just after logging, forest residues are the leftovers--the material without enough value to justify its removal. The material is organic, the product of photosynthesis and mineral uptake. Like merchantable logs, its cells contain cellulose, lignin, ash-forming minerals, and extractives. But the pieces are too small or the wrong shape, the chemical components are in the wrong proportion, or the material is in various stages of decay. Trees that are dead and standing, fallen, live culls, trees too small to harvest, and tree tops, bark, branches, leaves, cones, and stumps are included. Stumps are especially prominent when attached to a root system uprooted during a windstorm or rooted out during roadbuilding. Understory brush species are included, especially if they have been knocked to the ground during a logging operation. Some merchantable logs may have been missed by the loggers.

Forest residues are "residues" only in a utilization sense and cause public concern only for a short period during a forest rotation. This period begins with timber harvesting, which removes merchantable material. It ends as residues decay and are incorporated into the soil, as tree seedlings grow and hide them from view, or as the canopy of a thinned stand closes. Large logs left as residues, especially western redcedar and Alaska-cedar, extend the decay period and may impede intensive management of the new stand.

Viewed from a long-term perspective, residues are an essential part of the forest ecosystem. Man disturbs the ecosystem by harvest cutting, much as nature disturbs it by fire or wind damage. This changes the energy flows, food chains, and the structure; but the ecosystem remains and builds anew, again tending toward the characteristic hemlock-spruce forest. The long term as well as immediate effects should be evaluated in residue management decisions.

Residue treatments may have detrimental as well as beneficial consequences. For example, burning, which has been practiced widely in southern parts of the hemlock-spruce type, reduces the nutrient capital; creates smoke, reducing visibility; and creates the risk of fire escaping control and damaging adjacent property. Treatment alternatives must be carefully considered and the best course of action determined. In some situations, no treatment at all may be best. This will be increasingly true as residue volumes continue to be reduced by improved standards of utilization.

Here, we look generally at forest residues as part of the ecosystem, then more closely at dead and decaying material after logging, considering the fire

hazard and the silvicultural, physical, chemical, and esthetic effects of this material. Residue treatments are described, evaluated, and recommended. We hope this report will provide an improved scientific framework for management decisions. With the recent emphasis on environmental quality and improved utilization, questions of residue management are timely.

VOLUME AND ARRANGEMENT

Several factors lead to high residue accumulation in hemlock-spruce ecosystems, including high basic productivity of the species (Fujimori 1971, Dimock 1958), infrequent wildfires, a preponderance of decadent old-growth stands with high percentages of defect, and the cool climate and high rainfall resulting in mor humus and accumulation of organic debris on the forest floor (Gregory 1960). Southward, high productivity is the main cause of residue accumulation while lack of wildfire, old-growth stands, and mor humus are more important in residue accumulation in the cooler northern parts of the range.

The volume and arrangement of residues vary widely depending on the age and size of the timber harvested, its volume per acre and percent of defect, the volume in undersize trees and unwanted species, topography, logging method, utilization standards, contract requirements, market conditions at the time of logging, and even the attitude of the logger who harvested the timber. The variation in tree size, characteristic of climax or near-climax stands, contributes to residue volume because felling of large trees tends to break up small ones and heavy equipment needed to get out the large logs tends to break small logs. In Alaska, where logs are rafted to the utilization plant, small logs and chunks may be left in the woods because they will escape from rafts and be lost.

Residue volume generally increases with stand age and successional development (Howard 1973). Vigorous young stands may be essentially free from defect with tops, limbs, and stumps making up almost all residue volume. Occasional stem sections bucked out due to felling breakage or forked tops are present. There may be some undersize trees, standing or down. But there are very few cull logs that in old-growth stands add so much to residue (fig. 2). There is little understory vegetation. Most young stands are harvested in the southern parts of the hemlock-spruce type where demand for logs is high and economic conditions permit taking logs to a smaller top diameter and shorter length than farther north. Residue exceeding 4 inches (10 centimeters) in diameter, 4 feet (1.2 meters) long, and 10 percent chippable measured on six industrial forest clearcut areas averaged 1,332 cubic feet per acre (93.2 m^3/hectare).[1/] With a conversion factor of 25 pounds per cubic foot (400 kilograms/m^3) (bone dry) (Grantham et al. 1974), this is equal to 16.6 tons per acre (37.3 metric tons/ha). This did not include decayed material less than 10 percent chippable, stumps, understory vegetation, and fine material from branches and leaves. Branches and leaves were estimated by Fujimori (1971) at 18.6 tons per acre (41.7 metric tons/ha) in a dense 19- to 32-year-old stand.

[1/] Melvin E. Metcalf, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, personal communication, March 17, 1971.

Figure 2.--Logging slash remaining after clearcut logging of 125-year-old hemlock-spruce with little defect. Broadcast burning is not planned. Oregon coast, 1973.

Highest residue volumes remain after harvest of old-growth western redcedar (fig. 3). For example, clearcutting of one stand containing much western redcedar on the Olympic Peninsula left a gross volume of 18,604 cubic feet per acre (1302 m^3/ha) of residues over 4 inches (10 cm) in diameter. The weight was estimated at 227 tons per acre (509 metric tons/ha). Twenty to 40 tons per acre (48 to 90 metric tons/ha) should be added for the fine material (Dell and Ward 1971). Cedar stands generally have high residue volumes because most remaining stands are decadent old growth. Also, cedar tends to split or shatter during felling operations. There has been little demand for cedar chips and little market for low quality logs (Howard 1973).

Timber volumes are lower in Alaska because of lower site quality, but stands that are logged tend to be older and therefore more defective than in Oregon and Washington. Total volume of chippable wood remaining as residue may equal that in the Pacific Northwest. On 19 clearcutting units sampled in 1971,[2/] 1,329 cubic feet per acre (93 m^3/ha) of chippable material remained after yarding, a volume equivalent to 20 percent of the net merchantable cubic volume.

In Alaska, stands favored for harvest cutting have been the better, overmature, even-aged stands containing a high percentage of spruce. Such stands are less defective than uneven-aged climax stands, and the timber is more uniform in size. As logging shifts to more uneven-aged, near-climax stands, there is potential for greater residue volume (fig. 4). Offsetting this, as the value of wood increases and utilization standards improve, more small and low quality material will be removed from the woods (see footnote 2).

2/ Personal communication with Richard L. Davis, U.S. Forest Service, Region 10, Juneau, Alaska.

Figure 3.--Logging slash remaining after clearcut logging of an old-growth hemlock-spruce stand with a high proportion of western redcedar. Cedar shake bolts have been salvaged. Olympic Peninsula, Washington.

Figure 4.--Residue after harvesting of a near-climax hemlock-spruce stand, Thomas Bay, Alaska, 1972.

Utilization standards in hemlock-spruce forests have varied with economic conditions, but there has been general improvement over the years with smaller and more defective logs becoming merchantable. Early day loggers seldom took top logs less than 30 inches (76 cm) in diameter. Today, 6 inches (15 cm) is common and a 4-inch (10-cm) top is the rule on some ownerships. The percent of sound wood that a log must contain before it is taken has dropped dramatically. There is a market in Oregon for utility logs which have a sound chippable content of at least 50 percent of the gross scale. Thus, there has been a downward trend in logging residue volumes. Also contributing to this trend in Oregon and Washington is the increasing proportion of the annual harvest in young stands with little defect. Residues are being reduced still further by periodic thinnings which remove defective trees and reduce levels of growing stock. This downward trend in volumes of residue has alleviated some detrimental effects of residues such as fire hazard and physical obstruction to planting and thinning. It also has reduced beneficial effects; residues protect the soil from erosion and serve as a source of nutrients for growth of the new stand.

The arrangement of forest residues after logging is greatly influenced by the logging method. High-lead yarding leaves numerous narrow skid roads radiating out from the landing like the spokes of a wheel. Disturbance increases toward the landing as skid roads run together and more logs are yarded along each section of road. Slash tends to be pulled into the landing with the logs, and invariably, a deep pile remains there after yarding is finished. Skid roads are narrow and have slash left in depressions. They do not form adequate firelines.

Tractor yarding tends to divide logging slash into sections bounded by tractor roads which often are quite adequate as firelines. This facilitates control of wildfire but requires extra effort in setting fire for a prescribed broadcast burn.

Grapple yarding, in which at least one end of a log is lifted free of the ground, causes less disturbance and usually leaves a more uniform distribution of slash than high-lead or tractor yarding. Skyline yarding in which logs are soon lifted free of the ground causes still less disturbance, leaving a quite uniform slash distribution (Ruth 1967). Helicopter yarding which essentially lifts logs directly upward causes the least disturbance, and logging slash generally remains where it landed as the trees were felled and limbed.

Numerous red alder stands within the hemlock-spruce type present a special residue management problem. The most common management objective is to convert alder forest to hemlock-spruce or hemlock-fir, usually by clearcutting and planting. At rotation age, alder stands have much less biomass than conifer stands (Worthington et al. 1960), and residue volumes are correspondingly less. But alder characteristically has a rich understory of shrubs and herbs (Franklin and Pechanec 1968) which becomes part of the residue. The resulting tangle of logging slash and brush obstructs travel and interferes with planting operations. The brush overtops and suppresses hemlock and spruce seedlings.

ECOLOGICAL EFFECTS OF FOREST RESIDUES

EFFECTS OF SEEDLING ESTABLISHMENT

Harvest cuttings and the resulting accumulation of residue should be designed to leave an environment suitable for establishing a new timber stand. Residues often dominate the site and therefore are a major factor in seedling establishment.

Residues can be suitable seed beds for establishment of both hemlock and spruce, but their suitability depends on the stage of decay and moisture and temperature conditions. Fresh logging residues are unsatisfactory seed beds (fig. 5); but after decay is well advanced, the radicle from a germinating seed can penetrate the surface, and the decaying wood provides adequate nutrition for seedling survival and growth. Litter covering the surface further improves the seed bed and may speed decay of the underlying wood. In contrast to hemlock and spruce, Douglas-fir and red alder seldom become established on rotten wood.

Logging residues intercept natural seed fall or aerially sown seed. They cover mineral soil seed beds, obstruct the movement of planting crews, and make impractical maintenance of a specified spacing of planted trees. Slash accumulations contribute to the clumped tree distribution often apparent in young hemlock-spruce stands. Slash-caused openings tend to seed in eventually, but the delay retards stand development, causing variation in height and age in the new stand.

Moisture and temperature are particularly important. In the southern portion of the range, organic material often dries before the root from a germinating seed can penetrate to adequate moisture, and organic seed beds may develop lethal surface temperatures more often than mineral soil. Exposed rotten wood or duff generally is unsatisfactory for seedling establishment (Minore 1972). A few

Figure 5.--Fifteen years after clearcutting on an exposed ridgetop, this decaying log remained nonstocked while spruce seedlings became established on the soil surface nearby, Cascade Head Experimental Forest, Oregon.

sunny days during the germination period can cause heavy seedling mortality.[3/] Consequently, most natural regeneration on southern clearcuts is on mineral soil (fig. 5). There are exceptions, as when the organic seed bed is well shaded or the weather remains wet or at least cloudy during germination and initial seedling establishment. Over time, seedlings do become established on organic seed beds. For example, Morris (1958a, 1970) reported on nine paired plots in a long-term study on coastal Oregon clearcuts where natural regeneration became established on both mineral soil and organic surfaces. However, production may be lost waiting for suitable weather conditions and for fresh residues to decay.

On northern clearcuts where cloudy weather and drizzle are more common during the germination periods, organic seed beds usually retain adequate moisture for seedling establishment. Most seedlings become established on organic seed beds. Partial shade provided by moderate amounts of logging slash has been shown to improve early survival of spruce and hemlock on mineral soil during an abnormally dry summer in Alaska (Harris 1967).

Under a forest canopy, the environment is cool and moist and rotten wood is a more satisfactory seed bed than in the open. Western hemlock and, to a lesser extent, Sitka spruce commonly become established here. Under coastal Oregon stands where there is less than 40 percent full sunlight, seedlings usually are larger and more abundant on rotten logs than on the duff-covered forest floor (fig. 6). When sunlight is over 40 percent, seedling occurrence is about the

Figure 6.--Natural hemlock regeneration on a rotten log under a 125-year-old hemlock-spruce stand. Cascade Head Experimental Forest, Oregon.

[3/] Robert Harvey Ruth. Differential effect of solar radiation on seedling establishment under a forest stand. Ph.D. thesis, Oregon State University, Corvallis, 176 p., illus., 1967.

same on these two seed beds (Minore 1972). Sitka spruce also will become established on decaying residue material if the overstory is moderate or less in density. Colonnades of Sitka spruce growing on decaying logs are a familiar sight in coastal forests.

Decayed wood is a suitable planting medium for Sitka spruce and also for Douglas-fir seedlings in coastal Oregon. Berntsen (1960) planted 200 seedlings on north and south slopes of a clearcut area where decayed wood was sufficiently deep that roots did not initially contact mineral soil. Other seedlings were planted on nearby mineral soil. Survival after four growing seasons was approximately the same in both planting mediums for both species and on both aspects (table 1).

Height growth of Sitka spruce was significantly better on rotten wood, but Douglas-fir grew about the same as on mineral soil. There was 14 inches (360 millimeters) of rainfall during the first growing season after establishment, probably contributing to the good survival.

Forest residue seed beds sometimes are an advantage to hemlock and spruce regeneration because few competing plants are able to grow on them. When only occasional seedlings are found in brush areas, almost invariably they are growing on rotten wood. Berntsen (1955) examined a clearcut area in coastal Oregon 6 years after logging and found rotten wood seed beds 97 percent stocked compared with 83 percent for mineral soil. The difference was attributed to competing vegetation which thrived on mineral soil and tended to crowd out tree seedlings. The shrubs and herbs did not do well on rotten wood, and tree seedlings essentially were free to grow there. Plots completely covered with a layer of limbs and logging debris were 67 percent stocked. Stocking was 62 percent on plots dominated by brush and herbaceous vegetation.

Table 1.--*Survival and total height of Sitka spruce and Douglas-fir 4 years after planting on decayed wood and on mineral-soil microsites*

Species and aspect	Survival		Total height	
	Mineral soil	Decayed wood	Mineral soil	Decayed wood
	- - - - *Percent* - - - -		- - - *Inches* (cm) - - -	
Sitka spruce:				
Northerly	98	98	29 (74)	43*(109)
Southerly	84	80	36 (91)	47*(119)
Douglas-fir:				
Northerly	90	90	25 (64)	25 (64)
Southerly	66	62	32 (81)	29 (74)

* Difference significant at 95-percent level.

Hemlock and spruce seedlings often invade openings dominated by other vegetation by becoming established on top of logs that have fallen into the opening from an adjacent timber stand.[4/]

There are several incidental ways in which forest residues affect tree seedlings. Bark may slough off a log or stump and cover nearby seedlings. Some seedlings become established under logs or large limbs, only to have the leader grow up into them and be damaged or grow around them causing a deformity. Sometimes the residues settle to the ground and crush seedlings. Other seedlings are damaged as their leaders sway in the wind and rub against residue materials. Residues tend to creep downslope under the weight of a heavy snowpack, destroying small seedlings in their path.

Residues also limit access to tree seedlings by cattle and big game, thereby reducing browsing damage. On the other hand, they provide shelter for the small mammals that damage seedlings.

Where frost damage is a problem, forest residues intercept outgoing longwave radiation and tend to slow nighttime cooling. They also slow cold air drainage. The net effect is variable.

In Alaska, Harris and Farr (1974) noted that on alluvial streamside sites subject to flooding, Sitka spruce and western hemlock seedlings become established alongside stumps or atop decayed logs or debris, thus avoiding the intermittent high water.

The foregoing relationships between hemlock-spruce forest residues and tree seedlings can be used to influence seedling establishment. Historically, even large clearcuts have seeded in well; so there is little risk of general regeneration failure. The major concerns are to speed seedling establishment, improve spacing, and control species composition. Residue management affects all of these.

Thinning of near-rotation-age stands and the slow opening of the canopy as stands become overmature normally result in establishment of hemlock and some spruce seedlings in the understory (Farr and Harris 1971). Most seedlings become established on decaying residue material. Usually there are too many. If the seedlings are free of mistletoe, overstory removal should be designed to destroy some seedlings but to leave enough well-spaced seedlings for full stocking. Techniques for doing this are not well developed, and research and experience are needed. But to the extent that it can be done, planting will be avoided and costs of precommercial thinning reduced.

Regeneration time can be shortened by planting rather than waiting for natural regeneration. Depending on volume, some residue disposal may be needed to uncover planting sites and facilitate movement of the planting crew. The objective should be to distribute residues to expose properly spaced planting sites. The remainder of the area should be left slash-covered to restrict unwanted natural regeneration which, in this case, would only result in costly precommercial thinning at a later date.

[4/] Eric Duncan Davidson. Synecology features of a natural headland prairie on the Oregon coast. M.S. thesis, Oregon State University, Corvallis, 79 p., 1967.

Much progress toward desired slash distribution can be accomplished by selecting an appropriate yarding system. If the timber stand is young and has little defect, minimum ground disturbance--as with helicopter, balloon, or skyline yarding--may expose sufficient planting sites. With more residue volume, more disturbance, as with grapple yarding, may be appropriate. High-lead would provide still more. Yarding of unutilized material to the landing will further reduce the volume of residues left on the area. This reduction can be controlled if dimensions of material to be removed are specified. Its removal will increase disturbance of the area and expose more mineral soil for planting. In the southern hemlock-spruce range, additional exposure may be obtained by broadcast burning.

Residue treatments greatly affect species composition of the new timber stand. Advance regeneration runs strongly to hemlock, so minimizing disturbance of the site favors this species. Increased disturbance destroys hemlock seedlings and exposes mineral soil. The opportunity for spruce on bare soil is better than for hemlock. It is more of a pioneer species. Exposing mineral soil also favors Douglas-fir if a seed source is available--also red alder, frequently causing it to become a major competitor on sites where conifers are preferred.

SOIL AND STREAM EFFECTS

Logging residues cause soil loss and stream sedimentation when they accumulate in stream channels and trigger debris-mud flows. This problem is most common in high rainfall areas and in steep "V-notch" ravines (Swanston 1974, Bishop and Stevens 1964). Accumulation of tops, branches, and other logging residues in stream channels may form dams that obstruct waterflow and sometimes cause shifting of the streambed. During high water, these dams can wash out, initiating a debris-mud flow that collects downstream debris and soil as it goes and scours the channel clean for considerable distances (fig. 7).

This process occurs where no harvest cuttings have been made--when natural residues such as snags and windthrown trees accumulate. On logging areas, accumulation of branches, logs, and other residues in streams may accelerate the process. Where debris-mud flows occur, stream gradient usually is too steep for use by fish populations; however, debris and sediment may be carried downstream to lower gradient sections used by fish.

When streams have a resident fish population or serve as spawning streams, the occasional introduction of natural residues causing pools and riffles tends to improve local fish habitat (Brown 1974) but, if extensive, may obstruct fish movement. The introduction of logging residues may also disrupt the natural habitat and reduce rearing space (fig. 8). When debris dams wash out, gravel beds may be scoured, covered, or otherwise destroyed as spawning areas (Bishop and Shapley 1963, Narver 1971), and new dams may form downstream. Residues, particularly bark, chips, twigs, and needles, may become intermixed with spawning gravel and impede waterflow carrying oxygen to fish eggs. The oxygen demand as this fine organic material decays may deplete oxygen supplies (Gordon and Martens 1969, Servizi et al. 1970, Ponce 1974, Reed and Elliott 1972, Lantz 1971). Accumulation of such residue in stream gravel can also decrease living space for stream invertebrates which are used as food by fish (McCrimmon 1954) (fig. 9).

Figure 7.--Debris-mudflow from a steep ravine, Maybeso Valley, Prince of Wales Island, Alaska: A, Debris-choked stream channel before flushing; B, debris deposit on gentle topography.

Figure 8.--Forest residues may choke streams and hinder or block migration of fish. Tributary to Fish Bay, Chichagof Island, Alaska. (Photo, courtesy Alaska Department of Fish and Game.)

Figure 9.--Small residues such as bark and wood chips, twigs, and needles damage fish habitat in spawning and rearing streams. Seal Bay, Chichagof Island, Alaska. (Photo, courtesy Alaska Department of Fish and Game.)

On flat areas, residues may plug stream channels, raise the water table in the soil, and destroy the adjacent forest crop.

Harvest cuttings must be conducted in a way that will keep residues out of streams. Protection can best be provided by falling and yarding timber away from streams, with immediate clearing of debris if necessary (fig. 10). If residues do get into stream channels, they should be removed promptly with minimum disturbance and placed above high water level. Care must be taken so that stream clearing does not break down streambanks and damage them (fig. 11) (Lantz 1971, Reed and Elliott 1972). Logs should not be skidded in or across streams. Detailed rules for stream protection have been written by individual States and are backed by State law (Oregon revised statutes 527.610 to 527.990 (Oregon State Legislature 1971); Washington 1974 Second Substitute House Bill 637 (Washington State Legislature 1974); British Columbia Forest Service;[5] Oregon Forest Protection Association 1972; Washington Department of Natural Resources 1974; Alaska statutes 16.05.870-900,16.10.010-040 as revised through 1974; Alaska Department of Environmental Conservation 1973).

Figure 10.--Fish habitat may be protected by falling and yarding timber away from the stream, followed by hand clearing if necessary. Tributary to Luck Lake, Prince of Wales Island, Alaska. (Photo, courtesy Alaska Department of Fish and Game.)

[5] British Columbia Forest Service. Interim provincial guidelines relating to prescribed burning in site rehabilitation. File No. 09565, 5 p. July 1974. Victoria.

Figure 11.--Debris removal by heavy equipment damaged stream banks in this tributary to Shelikof Creek, Kruzof Island, Alaska. (Photo, courtesy Alaska Department of Fish and Game.)

Forest residues serve as a storehouse for an important part of the nutrient capital of a hemlock-spruce ecosystem. Depending on the residue volume and fertility of the mineral soil, they contain variable proportions of the total nutrient supply. The proportion is higher in Alaska where residues decompose slowly, lower in the southern portion of the range where they decompose rapidly. On nutrient-deficient forest soils and soils low in clays or organic material, the nutrient capital stored in forest residues, especially in the forest floor, is needed for tree nutrition. Only large residues should be removed from these areas, and the forest floor should not be reduced by burning.

The surface of the mineral soil needs to be protected from the impact of raindrops and other disturbance. Usually the litter layer of needles and small twigs on the forest floor is sufficient, but some of this may be scraped away during logging. Depending on the degree of aggregation in the surface soil, exposed soil particles may be dislodged by the splash of raindrops and plug pore openings. This reduces infiltration rate and increases the possibility of surface runoff. Surface water picks up still more soil particles which seal off additional pore spaces, and erosion may result. Forest residues can serve as a substitute mantle protecting the soil. The need usually occurs on steep slopes where disturbance is difficult to avoid and the potential for erosion is great. But coastal soils vary widely in erodibility. Soil exposure which may be inconsequential with some may be disastrous with others. Soils developed on recently stabilized sand dunes particularly are subject to erosion if exposed. Part or all of the residues on such areas should be left to protect the soil. Together with shrubs and herbs, they hold back downhill movement of soil during winter storms or during rare periods when dry ravel may occur. Lopping and scattering of residues and special fire protection measures on such areas are preferred alternatives to broadcast burning.

Residues affect the physical properties of underlying soils. As they decay, the organic compounds in the surface soil often cause aggregation of fine soil particles and this usually improves the water infiltration rate (Rothacher and Lopushinsky 1974). Shade afforded by residues reduces evaporation from the soil surface. Operation of machinery over the surface will, under adverse moisture conditions, compact the soil and reduce infiltration rate, permeability, and gaseous exchange (Froehlich 1973). Thus, machine piling of residues to reduce fire hazard or for seedling establishment may have adverse effects as well.

EFFECTS OF RESIDUES ON ESTHETICS

Forest residues have important effects on esthetics of hemlock-spruce clearcuts, effects that increase with residue volume and as more people come in contact with cutover land. Volume-related effects will decrease as logging shifts to second-growth stands. However, in Alaska, logging of old growth will continue for decades; and residue volumes may even increase as logging shifts to more decadent stands.

Although public reaction to timber harvesting usually focuses more on the loss of tree cover than on logging debris, the presence of large amounts of residue is considered by many people as evidence of forest devastation (Wagar 1974) and a waste of wood fiber.

With recreational use of coastal forests mostly water oriented, distant views of cutover areas are particularly important. Color and general appearance are major factors. During the first year after clearcutting, logging debris, stumps, and the organic duff layer are brown, contrasting with the green of surrounding timber. From the first to fourth year, green plants cover the ground. Stumps, logs, and tops bleach to gray. The green plants blend with surrounding timber, and the major contrast is between adjacent ground vegetation and the gray of the residues. From 5 to 8 years after clearcutting, residues become covered by ground vegetation and major contrasts disappear. A new hemlock-spruce forest canopy usually closes over the area 15 to 20 years after clearcutting.

Direct contact with forest residue is of greatest concern in areas of high public use, usually near roads and campgrounds where berrypicking and hunting are important. Berrypicking is increasing in importance in Alaska. Clearcuts are suitable for berrying as shrubs develop in the increased sunlight, until they are overtopped by the new forest canopy. Clearcuts also are suitable for deer and bear hunting during this period.

Snags are a special component of forest residue, especially important in old-growth forests. The esthetic value of snags is debatable. A few snags left in the proper setting can be esthetically pleasing, whereas many snags located throughout a cutting unit may not be (fig. 12). Snags often have value as nesting sites for wildlife but may also interfere with timber management activities. Conflicts over the disposition of snags may develop, based on concern for various resources.

At present, snags are felled on most National Forest cutting units. However, in some cases retention of a certain number per acre has been required for use by wildlife. Blanket rules governing snag disposition on all cutover areas are not desirable. Ideally, a compromise for snag retention on each cutting unit should be worked out by landscape, wildlife, and timber management specialists.

Figure 12.--Eight years after logging, most residues are hidden by conifers but snags remain in view. The esthetic value of snags varies by their numbers and distribution and by the individual tastes of viewers, Maybeso Valley, Alaska.

The adverse esthetic effects of logging residue may be reduced in various ways; by rearranging or reducing the amount of residue left after logging, by separating the public from timber harvest operations, and perhaps by education to show why residues are created and some of their positive benefits. Some combination of the following would improve esthetic effects of logging residue in the hemlock-spruce type.

1. Improved utilization. Improved utilization would directly eliminate much of the problem, especially that of large residues.

2. Cleaner foreground areas along travel routes. The condition of the foreground has a great effect on one's interpretation of the view of an entire cutover unit. Also, the greatest public use of cutover areas is adjacent to roads. Removal of large residues from along travel zones would substantially reduce adverse esthetic reactions. YUM might have application for cleanup of foreground. In more remote situations, piled unmerchantable material could be burned.

3. Layout of cutting units. Whenever possible, cutting units should be designed to provide screening from public view. Leaving strips along roadways or waterways and placing cutting units to take advantage of topography would

help reduce adverse esthetic effects. When necessary to cut timber along travel routes, small cutting units would be less objectionable than large ones and would attract less close attention to residues.

4. Residue treatment. Broadcast burning or piling and burning substantially reduces the amount of residue and greatly improves access. Blackening of remaining debris causes it to blend in better with the surrounding soil surface, thereby reducing its visibility. But clearcuts revegetate quickly, providing a contrast between the green foliage and black residue.

5. Education. The public needs to be better informed about residue management. They will be better prepared for the reality of woods operations if they know the roles played by forest residues in nutrient cycling and forest regeneration and understand the economics of forest utilization.

Residues created by precommercial and commercial thinning and shelterwood cutting also have esthetic effects but less so than those following clearcutting. Volumes are less, sizes smaller, and much of the residue is screened from view by the residual stand. Residues from precommercial thinning substantially reduce travel through an area until thinned stems have settled to the ground; then the area has a parklike appearance more pleasing than that of an unthinned stand.

EFFECT OF RESIDUES ON INTENSIVE TIMBER MANAGEMENT

Forest residues on a logged area are a physical obstruction to intensive management of the new stand. Cull logs, stumps, and piles of debris get in the way of men and equipment during thinning and other cultural operations; some large residues persist until the next harvest cut. Obstructions make stand treatments more costly and may cause them to be deferred or rejected. The yield potential of the site, therefore, may not be fully realized. This problem is most acute after logging of defective old growth or stands with a high proportion of cedar (fig. 3).

The impact of residues on intensive management of the new stand should be estimated and considered in prescribing residue treatments to be applied after harvest cutting of existing stands.

EFFECT OF RESIDUES ON FIRE DANGER

Fire danger from accumulation and exposure of forest residues is of definite concern in the hemlock-spruce type, although less so than in drier forest types. The greater concern is in the southern part of the range where several major conflagrations have occurred (Munger 1944). Throughout the range, however, there always is danger of wildfire starting in forest residues.

Three major components of fire danger are fuel, weather conditions, and risk of ignition. Fuels usually are present in hemlock-spruce areas, often in great excess. Risk of ignition, always present to some degree, varies from very high in high-use areas of coastal Oregon and Washington to very low in remote areas of Alaska. Lightning hazard generally is low in coastal areas. The wet coastal climate is the major factor keeping down fire danger. Periods of dry weather are relatively rare in coastal Alaska. They increase southward until, at the southern end of the range, moist conditions in summer are maintained mainly by fog that moves in off the Pacific Ocean most evenings. Fire danger increases greatly when wind patterns associated with a continental high pressure area produce strong

offshore winds, replacing nearly saturated marine air with dry continental air. Most wildfires have occurred in the southern part of the range, and most residue management treatments to reduce the fire hazard have been applied there.

Without residue treatment, fire hazard in hemlock-spruce areas decreases gradually as needles drop off, fine materials decay or become compacted by winter snows, and growth of forest regeneration, brush, or hardwoods provide shade that keeps the residues moist.

In case of wildfire, unburned logging residues may offer so many obstacles that building a fireline through them in the face of spreading fire is impracticable. In this situation, a common procedure is to drop back to an area offering less resistance--a truck or tractor road, stream, preestablished fireline, or an area of recently treated residue. Resistance to control increases with depth of duff and rotten wood, also with rank growth of tree seedlings, brush, and herbs, but decreases with gradual decay of logging residue--the net result varying with locality.

DECAY OF LOGGING RESIDUES

Organic residues decay slowly, the rate depending primarily on presence of inoculum, moisture, temperature, and the decay resistance of the wood. These factors are affected in turn by degree of shading, cloudiness, slope, aspect, soil type, topographic situation, bark retention, and whether the slash has been burned. Temperature generally becomes limiting in the winter, the limitation increasing northward. Moisture generally becomes limiting in the summer, this limitation increasing southward.

The following account of decay of logging slash is from the Quatsino Region, British Columbia (MacBean 1941).

Years since logging	Stage of decay
1 - 3	Needles dry out and have mostly fallen. Fine twigs become brittle but still adhere to the branches.
4 - 6	Twigs flatten out.
7 - 9	Twigs less than 0.25-inch (0.64-cm) diameter have fallen. Small branches can be easily broken.
10 - 12	Slash well flattened, material less than 0.5-inch (1.3-cm) has fallen. Small logs become well rotted.
13 - 15	All small material decomposed. Small branches 2-3 inches (5-8 cm) in diameter still intact. Decay in logs well advanced.

Roff and Eades (1959) studied annual progress of decay in hemlock and spruce residue down to 6 inches (15 cm) in diameter and 8 feet (2.4 m) long in British Columbia and found that incipient decay occupied 20 percent of the total volume 1 year after logging. Advanced decay, where wood exhibited partial or complete disintegration of structure, was less than 10 percent. After 2 years, decay was proceeding at a high rate. Bark on logs hastened decay of hemlock only slightly, but bark definitely hastened decay in Sitka spruce. The proportion of brown and white rots increases annually in both western hemlock and Sitka spruce, with brown rots more prominent in hemlock, white rots in spruce. Growth of ground cover did not produce effective shade until the fourth year after logging. Decay was well advanced by this time, so shade was not an important factor in promoting it. Childs (1939) identified some 30 wood-destroying fungi attacking western hemlock, Sitka spruce, and associated Douglas-fir and Pacific silver fir.

Rate of heartwood decay varies among species, with western hemlock and Pacific silver fir most susceptible, followed by Sitka spruce and Douglas-fir; the cedars are most resistant. Large logs decay more slowly than small ones and butt logs more slowly than top logs. Lopped and scattered slash generally deteriorates faster than piled or windrowed slash (Aho 1974). Where relogging is planned for salvaging merchantable residues, it should be done promptly to avoid extensive losses from decay.

Although some of the slash-inhabiting fungi also attack living trees, their presence in logging residues may not greatly increase the risk of infecting the residual stand. Inoculum is already present from other sources in the forest, and rate of infection is governed mostly by occurrence of entry courts in living trees rather than absence of inoculum (Childs 1939, Aho 1974). Root rots such as *Fomes annosus* survive as saprophytes in stumps and roots after a tree is harvested and may spread to living trees through root contact (Nelson and Harvey 1974).

INSECTS IN FOREST RESIDUES

Hemlock-spruce forest residues provide food, shelter, and reproductive sites for many insect species. Some are forest pests, but most are beneficial in that they fragment the forest litter and facilitate its decomposition. Hemlock and spruce residues rarely contribute to a buildup of insect populations that attack living trees. Forest residues harbor ambrosia beetles which readily attack felled and bucked timber and trees felled by the wind or other damaging agents. They cause little or no damage to pulp timber but often seriously degrade saw logs or veneer logs. Ambrosia beetles and other insects provide entry courts for disease organisms which, in turn, speed decay of forest residues (Mitchell and Sartwell 1974).

In Alaska, a localized outbreak of Sitka spruce beetle (*Dendroctonus obesus*) occurred in 1941; it lasted several years. Origin of the infestation was thought to have begun in windthrown timber or in overmature live trees during an abnormally dry period.[6/] Although it could be possible for this insect to build up in logging slash, experience has not shown this to be a serious problem.

[6/] Report by R. L. Furniss and Ivan H. Jones, December 5, 1946. On file at Forestry Sciences Laboratory, Juneau, Alaska.

TREATING HEMLOCK-SPRUCE LOGGING RESIDUES

The most common method of handling hemlock-spruce logging residues is to leave them untreated; that is, to utilize as much material as practicable and leave the remainder to decay where it falls. This is least costly in current expense, but it may cost more in the long run. For example, in areas of appreciable fire danger, failure to treat residues can contribute to serious losses from wildfire. Other treatment alternatives are described below.

BROADCAST BURNING

Broadcast burning, or the controlled use of fire over an entire cutting unit, historically has been the most common method of treating residue in the southern portion of the hemlock-spruce range. Burning is less expensive than mechanical treatments and does not require heavy equipment that may expose and compact the soil. Use of fire is diminishing, although it still is a recognized residue management tool. Pressures are mounting for its elimination because of the adverse esthetic effects of smoke. Also, blackening of the burned area is distasteful to many persons. There are situations, however, in which danger of wildfire may reach levels where hazard reduction by burning is the best alternative. It is still a treatment alternative that warrants careful consideration by forest managers.

Effects of Burning on Fire Danger

The net effect of residue disposal by broadcast burning is a sharp reduction in fire hazard. Many clearcut areas in Oregon and Washington have been burned for this purpose. Most needles, twigs, and material up to 3 inches (8 cm) in diameter are consumed in a prescribed burn with most larger material consumed only in part (fig. 13) (Martin and Brackebusch 1974). Prescribed fires are set only under conditions where benefits are judged to outweigh detrimental effects. For example, spring burning, when soil moisture and moisture in large residues are high, consumes only the fine, flashy fuels, leaving the duff layers and large logs and chunks mostly intact. In general, prescribed fires burn much cooler and destroy less organic material than does wildfire.

Figure 13.--Broadcast burning consumed almost all residue material up to about 3 inches (8 cm) in diameter, leaving only the remains of larger logs as a continuing fire hazard, Siuslaw National Forest, Oregon. Divisions on stake indicate 1 foot (30 cm).

Most broadcast burning has been in Oregon and Washington where summer drought is more severe than farther north. But even here, burning is less common than in adjacent Douglas-fir forests farther inland. There summer drought is more common, wood is more resinous, and advance regeneration is less likely to be present. Needles drop from spruce and hemlock slash more readily than from Douglas-fir, reducing the rate of spread the first season. The rapid growth of brush and hardwoods in fog belt areas soon shades the slash and keeps it moist.

Prescribed fire can become wildfire. The risk is low in coastal forests, particularly where the residue area is surrounded by green timber, but it does happen and the risk must be evaluated when residue treatment is considered. Where fire danger is high, the greater risk may be to leave forest residues untreated.

Effects on Conifer Regeneration

Residue treatments by burning have important effects on the timing, amount, and species composition of natural regeneration. Broadcast burning destroys most advance regeneration and, unless the area is planted or seeded, delays seedling establishment until after the next seed crop. This may be several years, and many burned areas are planted to avoid risking this delay.

Gockerell (1966) measured average height of natural regeneration on burned and unburned clearcuts near Forks, Washington. Five years after logging and burning, weighted average height of hemlock, spruce, Pacific silver fir, and western redcedar seedlings on burned areas was 1.9 feet (0.6 m) compared with 3.7 feet (1.1 m) on unburned areas. Harris (1966) recorded similar results in Alaska where, seven growing seasons after burning, height of hemlock seedlings on a burned area averaged 3.7 feet (1.1 m) compared with 8.2 feet (2.5 m) on an unburned area. Broadcast burning obviously delays seedling establishment. On the other hand, if planting is planned, burning opens up the area and facilitates the planting operation. Residues are an obstruction to planting on both burned and unburned areas but are much more of a problem without burning. Planting is more costly on unburned areas because access is more difficult, and small slash and duff must be removed from most planting spots.

Since burning destroys most advance regeneration, burned areas initially have fewer seedlings than do unburned areas. But where burning exposes additional seed beds, the potential for subsequent regeneration may be greater than without burning. Hetherington (1965) recorded a 20-percent increase in suitable seed beds on burned hemlock plots on Vancouver Island and, after the third growing season, a 50-percent increase in the number of postlogging seedlings. In coastal Washington, Gockerell (1966) observed postlogging regeneration that had become established over a 4-year period on burned and unburned areas. In 2 of the years, more seedlings became established on unburned areas, in 1 year more came in on the burned, and in 1 year both regenerated about the same. Berntsen (1955) compared burned and unburned areas in the hemlock-spruce type on the Oregon coast. Through the fifth growing season, there was more established postlogging regeneration on unburned plots which, however, received 50 percent more seed. During the sixth season, the burned plots forged ahead and, by the end of that season, had 25 percent more established seedlings. Burning had delayed regeneration but had reduced logging residues to expose additional seed beds and had retarded competing vegetation. After a light broadcast burn in southeast Alaska which consumed small material but only blackened the duff layer, Harris (1966) found more postlogging regeneration on unburned plots but greater milacre stocking on burned plots and, therefore, better seedling distribution.

These variable results probably stem from interactions between seedlings, seed beds, and weather conditions. Where burning exposes mineral soil, the seed bed tends to remain cooler and apparently retains more moisture than an organic seed bed. Germinating seedlings have a better chance of surviving spring and summer insolation. A blackened organic seed bed exposed to the sun gets very hot and dry and becomes inhospitable to germinating seedlings. These conditions vary from south to north ~~and~~ are further influenced by the intensity of the prescribed burn. In the south where exposed organic seed beds are slow to regenerate, a burn should expose enough mineral soil for adequate stocking, leaving enough blackened organic material to avoid overstocking.

Harris (1966) found spruce seedling establishment was better and hemlock poorer on a burned area compared with an unburned area, indicating that burning might be used to increase the proportion of spruce. This is consistent with the role of Sitka spruce as a more seral tree species than western hemlock and characteristically ahead of hemlock in primary and secondary succession. Where a seed source is available, red alder and Douglas-fir also are favored by burning. Burning favors spruce by killing most advance regeneration, which almost invariably is hemlock.

The decision of whether to burn and at what intensity depends first on fire danger. In special cases, fire danger may be high enough that the greater danger is to leave the area unburned and risk wildfire which may burn not only the logging residues and established regeneration but surrounding areas as well. Second, the decision of whether to burn depends on the amount of advance regeneration--whether it's mistletoe free and undamaged--and the policy of the landowner regarding planting and species composition. These factors must be considered along with others mentioned in following sections. The effect of a burning treatment can be increased or decreased if appropriate fuel moisture conditions for the burning operation are specified.

A decision to utilize advance regeneration is also a decision that logging residues will be intermixed with the tree seedlings with the difficulties of residue treatment this involves. Increasing trials of the shelterwood system in southern hemlock-spruce forests emphasize the importance of this problem. With shelterwood cutting, the problem varies with rate of removal of the mature stand. Clearcutting with protection of advance regeneration leaves all the logging residue at one time. On the other hand, a shelterwood cutting with a seed cut and one or more removal cuts leaves logging residues over a span of several years with time for some decay to take place between cuts. A residue treatment decision should be made before each cut.

In coastal forests of Oregon and Washington, Douglas-fir often is a component of existing stands and is preferred as a replacement for Sitka spruce in the next rotation because of fir's higher stumpage value and because of the spruce weevil problem. In this situation, broadcast burning destroys much of the hemlock advance regeneration and opens up the area for planting. Generally, the fir is planted without waiting for natural seedings. The fir seed source may be inadequate; it may be a poor seed year; and generally, planting is needed to give seedlings a head start on competing vegetation. A decision to plant Douglas-fir is itself an argument for burning because the burn sets back the competing vegetation and cleans up the area for the planting crews. Some hemlock advance regeneration often survives the fire, and additional hemlock and spruce usually seed in to create a mixed stand.

Effects on Competing Vegetation

Besides its effect on tree seedlings and seed beds, burning facilitates subsequent establishment of tree seedlings by reducing vegetative competition for light, water, and nutrients. In Oregon and Washington, burning may be prescribed almost solely for vegetative control, the reduction in logging residues being only an incidental result. Many old-growth stands have low volumes per acre, heavy underbrush, and only scattered regeneration in the understory. Clearcutting without burning perpetuates the brush which, in turn, prevents establishment of new seedlings. Advance regeneration, much of which is destroyed during the harvesting operation, may be inadequate to stock the site.

Effects on the Soil

Effects of removing forest residues from the soil surface by burning depend on the kind of soil, intensity and duration of the fire, topography, weather conditions, and many other factors. There is considerable literature on burning effects; but of the little that pertains directly to the moist hemlock-spruce situation, most concerns the southern portion of the range.

Research by Morris (1970) in coastal Oregon showed that actual exposure of mineral soil due to controlled broadcast burning is quite limited. Intensity of burn on the surfaces of coastal plots was:

Classification	Percent of plot area
Light burn--duff, crumbled rotten wood, or other woody debris partly burned but not down to mineral soil; or where these were absent before the fire, logs not deeply charred	75.2
Moderate burn--the foregoing materials consumed or logs deeply charred but mineral soil under the ash not changed in color	14.2
Severe burn--top layer or mineral soil changed in color, usually to reddish; next one-half inch often blackened from organic matter charred by heat conducted through the top layer	0.1
Unburned	10.5
Total	100.0

Most of the surface was left with a charred but protective mat of organic material to receive the initial impact of raindrops (fig. 14). Morris' study was in the drier portion of the hemlock-spruce range. In more moist situations farther north, burning is less likely to consume protective forest floor material. Fahnestock[7] examined a 110-acre (44.5-ha) wildfire area on Chichagof Island, Alaska, and found no areas of hard-burned soil. Rapid influx of herbaceous and shrubby vegetation and establishment of tree seedlings provides additional protection throughout the hemlock-spruce type.

[7] George R. Fahnestock. 1970 forest residues. Memorandum to the files, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, August 12, 1970.

Figure 14.--Broadcast burning generally leaves a charred mat of organic material which receives the initial impact of raindrops and protects the underlying soil from erosion. July, after a spring burn, Oregon coast.

Austin and Baisinger (1955) pooled data from moderately burned and hard-burned areas and concluded that burning substantially reduced the organic matter content and moisture-holding capacity of the top half inch (1.3 cm) of soil. Effects were much less in the 2-inch (5-cm) layer and insignificant in the 6- to 12-inch (15-cm to 30-cm) layer. Tarrant (1956) also compared physical properties of soil from unburned, lightly burned, and severely burned areas. Soils under lightly burned slash had less macroscopic pore volume, more microscopic pore volume, about the same percolation rate in sandy clay loam, and greater percolation rate in pumiceous sandy loam. Total pore volume and bulk density were about the same. Severe burning had more detrimental effects on soil; but with only 0.1 percent of the soil in this category, the total effect is insignificant. Hydrophobic properties of soils may be increased by burning, thereby reducing the infiltration rate (DeBano et al. 1970). Light burning apparently will have little or no effect on the long-term geologic process of soil formation (Moore and Norris 1974).

In general, the main physical effect of broadcast burning on hemlock-spruce forest soils in the southern part of the range is increased exposure of mineral soil. This improves the regeneration potential, also the potential for erosion. But a prescribed burn normally exposes only a small portion of the soil, most of the effect being limited to the forest floor material itself (Morris 1970). The

effect can be controlled by proper timing of the burn. Generally, increased erosion due to burning of residues is limited to special topographic and soil situations. Erosion potential usually is highest on steep slopes but may be high on gentle slopes with erodible soils. Soils developed on recently stabilized sand dunes particularly are subject to erosion if the subsoil is exposed.

Burning also affects soil flora and fauna, but specific effects in hemlock-spruce forests are little known. Indications from other areas are that burning causes no major qualitative changes in composition, and capacity for rapid recovery is great (Jorgensen and Hodges 1970, Metz and Farrier 1971).

Effects on Tree Nutrition

Forest residues serve as a storehouse for an important part of the nutrient capital on many hemlock-spruce sites. Depending on the residue volume and the fertility of the underlying mineral soil, they contain variable proportions of the total nutrient supply. The proportion is high in podzol soil areas in the north with their thick accumulations of mor humus, lower in the south where the residues decay more rapidly and are incorporated into the soil. Part of the nutrient capital is hauled out of the forest as logs, but the nutrient-rich leaves and twigs (Cole et al. 1967) are scattered about as part of the forest residue.

A major effect of burning on nutrition is on timing of nutrient availability for tree growth. Nutrients are released during combustion and, except for nitrogen, most are left in the ash. Subsequent rains leach these nutrients into the soil where, in part, they become available for uptake by plants. Thus, nutrients, accumulated over a period of many years, are made quickly available. This quick availability is at the expense of slow release of nutrients through the decay process. Which schedule is more favorable to tree nutrition is not well known. The burst of nutrients from the ash often contributes to a lush growth of herbs and brush, which compete with tree seedlings for light and moisture and accumulate some of the nutrient capital in their tissues. These nutrients need to be recycled and again made available for uptake as trees become dominant in the ecosystem and their nutritional demands increase.

Research in other forest types has shown that some of the nutrient capital in forest residues is lost from the site during and after burning. In particular, much of the nitrogen is volatilized during combustion and lost into the atmosphere. This reduces the total amount of nitrogen. On the other hand, nitrogen concentration of the residual material may be increased. Nitrogen-fixing activity in the soil tends to be accelerated, so that after a few years the surface soil may have as much nitrogen as an area that was not burned[8/] (Wells 1971, Jorgensen and Wells 1971, DeBell and Ralston 1970, Knight 1966). Losses of other elements during burning are less. Although some ash is carried away on convection currents during the fire (Knight 1966, Allen 1964; also see footnote 8), the greater potential for loss is for nutrients in the ash to be leached or eroded away before they can be utilized by plants. Leaching tends to be more rapid in coarse, sandy soils than in fine soils. Nitrogen also may be lost from a site by leaching, with this loss increasing following burning (Fredriksen 1971).

[8/] Charles C. Grier. Effects of fire on movement and distribution of elements within a forest ecosystem. Ph. D. thesis, University of Washington, Seattle, 167 p., 1972.

Calcium and other salts included in the leachate make the soil more alkaline, a condition often more favorable to competing vegetation than to conifers. This alkalinity is short lived, however (Austin and Baisinger 1955, Tarrant 1956). Coastal soils with an average pH of 7.1 immediately after burning averaged a near-normal pH of 4.6 4 years later. This compares with nearby unburned soils where the pH ranged from 4.3 to 4.5 during the same period.

In Alaska, little information is available concerning the effects of burning on tree nutrition. Stephens (1969) found that organic matter rather than clay is the source of almost all the cation-exchange capacity of soils in coastal Alaska. Thus, a reduction in organic matter by burning could have adverse long-term effects on tree growth. On the other hand, Stephens et al. (1969) found that stands which originated after wildfire did not differ significantly in growth rate from stands originating after logging. In general, wildfire tends to be less severe farther north, with severely burned areas rare. On immature soils such as alluvium, glacial outwash, or till, care should be taken to preserve the surface organic layer as a source of nutrient capital and to reduce erosion.

The main nutritional effects of burning hemlock-spruce logging residues seem to be increased availability of base elements and short-term losses of nitrogen. Burning never adds to the nutrient capital of an ecosystem. It volatilizes nitrogen and creates the potential for loss of other nutrients. More research is needed on relationships between residue treatment and tree nutrition.

Effects on Esthetic Values

Controlled burning generally improves the appearance of a logged area by removing the tangle of logging slash and other residue, but it changes the appearance by making it black. The net effect varies from area to area and according to the feelings of the individual viewer. In either case, the appearance improves when green vegetation grows tall enough to cover the residues. Burning improves access to the extent that logging slash is consumed in the fire.

Most people do not like to see burning in progress. The production of smoke, blackening of the surface, apparent waste of fiber, and potential for uncontrolled spread are all negative esthetic factors. The important beneficial aspects of controlled burning are less obvious.

Effects on Streams

Clearcutting a forest crop increases exposure of the surface of a stream to direct rays of the sun. Depending mainly on aspect, width of stream, and disturbance of streamside vegetation, this may increase water temperature. In Alaska, maximum stream temperatures during July and August increased 9° F (5° C) after clearcutting (Meehan et al. 1969). Broadcast burning of streamside vegetation might further increase temperature. Clearcutting and burning also may result in cooler stream temperature or freezing during winter, thereby altering the development of fish eggs and alevins and affecting the time of fry emergence and entry into saltwater. The availability of terrestrial insects to fish also may be altered when streamside vegetation is burned.

Water temperature in small streams may increase dramatically during residue burning. A severe case occurred in Needle Branch on the Oregon coast, a V-shaped valley with steep slopes. Stream temperature rose from 55° F (13° C) to

82° F (28° C) during slash burning. This increase was enough that many juvenile coho salmon, cutthroat trout, and sculpin died during the burn. The population of cutthroat trout was severely affected, but the other fish population levels returned to normal within 2 years (Hall and Lantz 1969).

Above the high-water mark, burning of residues may affect water quality if the fire is hot enough to consume surface organic material. Additional mineral soil is exposed, and soil trapped behind residues may be released. Soil movement usually is slow, and effects may not be noted for some time if at all. Generally, erosion from prescribed burning is not a serious problem in coastal areas because burning does not greatly increase the percentage of exposed soil (Morris 1970). Also, encroaching vegetation may again stabilize the soil before it reaches a stream. In special situations, however, burning may contribute to stream sedimentation; and this possibility should be evaluated when residue management plans are developed.

Burning may reduce the infiltration rate of water into the soil (Austin and Baisinger 1955), and this tends temporarily to increase peak flows. To the extent that live vegetation is damaged or killed by fire, transpiration is reduced, leaving more water available for streamflow. To the extent that riparian vegetation is destroyed, diurnal variation in streamflow temporarily is reduced or stopped.

Effects on Air Pollution

Effects of prescribed fire on air quality are summarized by Hall (1972). He concludes that, "In general, the only penalty inflicted upon the environment by prescribed burning is a small and temporary decrease in visibility." Burning forest residue does not produce the sulfur oxides common to combustion of coal and oil. Production of nitrogen oxides is rare. Carbon monoxide and carbon dioxide concentrations were measured near the perimeter of an experimental burn of Douglas-fir residue in western Washington, and high concentrations at the site decreased rapidly to normal in both horizontal and vertical directions (Fritschen et al. 1970, Murphy et al. 1970a, 1970b). Hydrocarbons produced by burning residues are similar to or identical with natural products always present in the environment. Only small traces of low-molecular-weight, photochemically active compounds are produced (Hall 1972).

Close to a prescribed fire, dense smoke may be unpleasant from the standpoint of odor and lung or eye irritation. Locally, it can obstruct visibility to the point of causing traffic hazard. But mainly, smoke and haze obstruct distant views, thereby decreasing visibility and enjoyment of the outdoors. Strong objections to prescribed burning arise when the smoke drifts into urban areas where intensive efforts have been made to eliminate visible air pollution. This risk is reduced by burning in accordance with a smoke management system (Cramer and Graham 1971).

The decision for the land manager often is whether to reduce fire hazard by prescribed burning when smoke problems will be minimum, or to leave the hazard, hoping it never will burn. Leaving it runs the risk of wildfire with much greater smoke emission and the possibility that smoke will drift over urban areas. Prescribed fires can be set when airflow will facilitate smoke dispersal and carry it away from urban areas, when a hot convection column will carry smoke aloft, and when fuel is dry enough to burn with little smoke (Cramer and Graham 1971). The latter is difficult in hemlock-spruce compared with drier inland forests. Prolonged smoldering of slash piles after the main fire produces a lot of smoke which, without strong convection currents, tends to flow at ground level. Soil mixed in the slash aggravates this problem.

YARDING UNUTILIZED MATERIAL

YUM is a contract requirement on some public timber sales in Oregon and Washington. The requirement is that, in addition to removal of merchantable logs, all other logs above specified dimensions, regardless of defect, be yarded to the landing. YUM leads to improved utilization because, once logs are at the landing, more may profitably be hauled to a utilization plant. The dimensions usually specified are 8 inches (20 cm) or larger on the large end and 10 feet (3 m) or more in length; but these may be adjusted to any size. Thus, YUM may be used not only to improve utilization but to control the amount and size of residues left on a harvested area. This procedure normally removes the larger residues leaving only smaller pieces which tend to be broken up during yarding. Ecological effects are similar to yarding additional merchantable logs. There is added damage to advance regeneration, more exposure of mineral soil, and more removal of nutrient capital. The area is opened up for planting, and physical obstructions to thinning and other cultural treatments to the next crop are reduced. As with yarding merchantable logs, effects on the site vary widely depending on logging methods and equipment used. When YUM reduces fire hazard to the point that burning is avoided, its effects are substituted for those of fire.

Even though some of the defective material becomes merchantable after it is yarded to the landing and removed from the site, huge piles of unusable material remain (fig. 15). If they are left unburned, the area covered is at least temporarily taken out of production and the piles are in the way of managing the new stand. If burning is planned, it usually is delayed until late in the season when surrounding residues are wet from fall rains and danger of spread is minimal. Air pollution problems are much less then. The fire usually burns hot, and the underlying soil may receive a "hard burn" according to the definition of Morris (1970). This is of limited consequence because of the small area involved. Good survival and growth of planted seedlings have been noted on such areas.

Figure 15.--A pile of hemlock-spruce forest residues yarded to the landing.

YUM has not been required in Alaska or British Columbia, partly because small material tends to be lost from log rafts. It does offer an opportunity for control of the volume of residues in an environment in which treatment by burning often is not a viable alternative.

YUM may find little application in hemlock-spruce forests. The cost is high, sometimes over $400 per acre ($988 per ha) (Dowdle 1974); the need to reduce fire hazard is generally low; and adequate seed beds are usually available. But like other treatment alternatives, advantages and disadvantages should be carefully evaluated prior to harvest cutting. A positive cost-benefit ratio seems most likely where large volumes of cedar are present. As more and more residues become merchantable and are yarded as merchantable material, there will be less need to remove remaining unutilized material.

PILE AND BURN

Tractor piling of logging residues on clearcuts is sometimes done in Oregon and Washington, usually limited to areas of high public use or extreme fire hazard. Residues are pushed into rounded piles or long windrows, the latter being most common with high residue volumes. Tractor piling should be confined to gentle slopes where exposure of mineral soil will not cause erosion and should be limited to compaction-resistant soils.

Piled residues usually are burned during periods of moist weather when fire is unlikely to spread. The piles may be left unburned but then become an obstacle to intensive management of the next timber crop. The practice would be destructive to most soils in Alaska and is not recommended for use there.

BROWN AND BURN

Brown and burn or preburn spray is a combination herbicide-fire treatment, particularly useful where brush and herbaceous vegetation shade logging residues and obstruct seedling establishment--a common problem on hemlock-spruce clearcuts. The herbicide serves as a desiccant by killing live foliage which then dries in the sun. The leaves shrink and curl, letting sunlight through to the residues below. Both the killed foliage and the drying residue provide fuel for the fire to run across the area. The objective is to set back competing vegetation and open up the area for planting; hazard reduction is a secondary benefit. In this situation, it is impractical to depend on natural regeneration because brush and herbaceous plants come back too quickly. Rather, large, vigorous planting stock should be used; and even then, additional treatment may be needed to prevent overtopping.

Almost any effective and approved herbicide may be used as a preburn spray. It need not be selective to protect conifer seedlings, because presumably none are present. Dinitro is often used (Hurley and Taylor 1974). Another common formulation is 3 pounds acid equivalent of 2,4,5-T in an oil-water emulsion containing three-fourths gallon of diesel oil, plus water to make 10 gallons per acre (3.36 kg 2,4,5-T with 6.8 liters oil to make 93.5 liters per hectare).[9/]

9/ Ronald E. Stewart. Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon, personal communication.

OTHER RESIDUE TREATMENTS

Few other residue management treatments have been used following clear-cutting of hemlock-spruce forests. Next to broadcast burning, the most common treatment is to burn only heavy slash concentrations (fig. 16). The heaviest concentrations are at the landings. Others occur where the timber was particularly defective or where slash has accumulated in depressions. Burning usually is accomplished during the first fall rains when concentrated piles will burn but adjacent areas will not.

Figure 16.--Spot burning of residue concentrations, Oregon coast. A, Before; B, after.

Chipping residues and distributing the chips over the soil surface is a frequent suggestion. This would help protect the soil; but on steep slopes where protection is needed most, equipment for doing the job probably would damage the site more than leaving the residues untreated. Chipping is becoming increasingly common along roadsides. Unwanted vegetation and limbs trimmed from roadside trees are chipped, and the chips are blown into small piles. This improves driving safety and the esthetic appearance of the roadside.

A layer of chips on the soil surface affects the nutrient status at the site by increasing the surface area of the residues, thus speeding decay. This tends to tie up nitrogen in decay organisms and may temporarily limit tree growth (Cochran 1968). Not enough chipping has been done to fully evaluate the fire hazard of chips on the soil surface, although chips have been found to be a definite hazard along railroad rights-of-way (Jemison and Lowden 1974).

CONVERTING RED ALDER TO CONIFERS

In Oregon and Washington, red alder stands often are converted to conifers by a combination of logging, felling tall residues, broadcast burning, planting, and chemical brush control. The conversion usually is made on conifer sites previously logged or burned by wildfire, then abandoned without further treatment. Red alder and brush often invade and dominate such areas. Usually there are some conifers, growing singly or in small clumps. The usual management objective is to convert back to conifers because hemlock, spruce, and Douglas-fir all have greater stumpage value than alder and, with rotation ages currently used, greater productivity.

The procedure generally is to log all merchantable alder and conifers, in the process knocking down as many unmerchantable trees as possible. Remaining trees are felled. Then the area is broadcast burned to clean it up for planting and further set back brush and other vegetation (fig. 17). Planting is accomplished as soon as practicable after burning with large and vigorous planting stock that has a better chance of keeping ahead of sprouting brush. If planted seedlings later become overtopped, approved selective herbicide sprays are used. Red alder frequently seeds in again and also must be controlled.

Mechanical eradication of the alder and brush is an alternative approach (Gratkowski et al. 1973). Tractors equipped with brush blades may be used on gentle slopes where residues are pushed into windrows and later burned. On steep slopes, cable systems may be used to drag weighted drums, chains, or other tools through the alder and brush in preparation for burning. These mechanical eradication techniques are effective but quite expensive, and there is danger of causing soil compaction and erosion.

Large acreages of high-site forest land in coastal areas are now dominated by red alder and brush. Substantial gains in timber growth will come as this land is put back into full production.

TREATMENT OF THINNING RESIDUES

Residues from hemlock-spruce thinnings generally have been left untreated. Fire danger under the shade of a residual stand has not been great, even though most thinnings have been in the drier portion of the hemlock-spruce range. Residues sometimes are lopped and scattered to put them in contact with the soil where moisture will speed decay. Lopping and scattering often is prescribed along road rights-of-way where the risk of fire is high and esthetic values are particularly important.

Figure 17.--A stand of red alder encroached on this conifer site which is now being converted back to conifers by logging, slashing, broadcast burning, and planting. The alder stand with occasional conifers can be seen in the background. Tillamook County, Oregon.

In shelterwood cutting, residues sometimes are piled in the larger openings and burned. This clears the area for seedling establishment and reduces fire hazard. Hand piling usually is preferred over machine piling because tractors are limited to gentle slopes; and they may compact the soil, damage established regeneration and surface roots of the residual stand, and expose mineral soil to erosion.

Precommercial thinning in hemlock-spruce is standard practice on many public and private ownerships in Oregon, Washington, and British Columbia. Both powersaws and chemicals are used, with saws most common. These thinnings leave a high fire hazard, particularly while foliage remains on the crowns. The small limbs and foliage are light, carry fire rapidly, and are only partially shaded from the sun. With chemical thinning, the trees remain standing; this slows

decay because the wood dries out too much during dry weather to support fungal growth. Limbs usually decay and fall off first; then the roots decay, and the main stem topples over. With powersaw thinning, some trees remain upright but most fall over and remain suspended above the ground on their limbs. The main stems are not heavy enough to crash to the ground. The resulting tangle of stems and branches strongly discourages foot travel (fig. 18). It takes 5 to 10 years for the main stems to settle to the soil surface unless borne down by a heavy snowpack. Thereafter, decay accelerates rapidly. Extra fire protection usually is provided for the years it takes these thinning residues to decay or be covered with understory vegetation.

Residues from precommercial thinning generally are left untreated. Broadcast burning is impractical because of intermingled crop trees. Piling and burning would be difficult because the slash is too light and springy to form compact piles. Cut trees are pulled out of roadways and roadside ditches, and sometimes these are chipped. Slash on the general area usually is left to decay over time.

Figure 18.--Residue from thinning of dense, 19-year-old hemlock-spruce stand, Maybeso Valley, Alaska. An average of 6,300 trees per acre (15,565 per ha) averaging 1.6 inches (4 cm) in diameter were cut, leaving crop trees spaced 16 by 16 feet (4.9 by 4.9 m).

CURRENT PRACTICE

Residue management is in transition in the hemlock-spruce type as well as generally in the Pacific Northwest. Improvement in utilization, gradual over the years, recently has been more rapid--both in harvest of smaller sizes and better utilization of defective material. Greatest reductions in residue volumes have been near utilization plants where transportation costs are low. Others come from careful felling and bucking to reduce breakage, cutting lower stumps, taking shorter chunks, utilizing to a smaller top diameter, handling logs more carefully, and using defective logs.

Increased utilization of timber sometimes is accomplished by prelogging small trees that might be broken if felled and yarded with the main crop. Relogging--logging the area again, usually with smaller equipment than the main harvesting operation--also may be used to improve utilization. Relogging is common when periods of high log prices make profitable removal of more logs from the area. Areas with western redcedar slash often are salvage logged for shake bolts.

Soil is recognized as the basic resource, with increased attention given to short- and long-term effects of residues on soil stability and nutrition. Timber harvesting and road construction are planned to keep residues out of streams. If residues fall into streams, they should be removed and placed above high-water level.

Fire regulations in each State and most timber sale contracts on public land require felling of snags and unmerchantable trees on clearcut areas. The main objective is to reduce fire hazard. The need for snag felling, particularly in the wetter parts of the hemlock-spruce type, needs further study.

The appearance of the forest is given special consideration, with most public and some private landowners designing clearcut boundaries to blend into the landscape and present a more pleasing appearance than would a rectangular clearcut. Forest residues are often screened from view until they have been overtopped with tree seedlings or other vegetation.

Additional practices vary from south to north and are best discussed by locality.

OREGON AND WASHINGTON

Treatment of logging residues differs among forest landowners in Oregon and Washington. Those who have heavy slash accumulations, summer drought conditions above average for the type, or a high proportion of western redcedar slash tend to favor burning. Others require YUM, then wait until late fall and burn the large concentrations at the landing. Still others forgo the added yarding cost for the unmerchantable material and burn the heavier concentrations at the landings and out on the harvested area. Others leave the slash untreated.

Public land managers often are faced with increased fire risk due to heavy public use, and this tips the scale in favor of burning. Private landowners more often restrict use of their property during periods of extreme fire danger, thus reducing the risk of wildfire. Some of them strongly oppose burning of any kind. Often they have a nearby utilization plant and are able to remove quite small material from the area, thereby reducing residue volume.

Arrangement of cutting units is an important factor influencing residue management decisions. When a clearcut area is surrounded by green timber, as in the patch-cutting system, wildfire normally can be confined to the vicinity of the clearcut area because the surrounding hemlock-spruce timber stand usually remains damp enough to slow wildfire, facilitating its control. General fire hazard, therefore, is not greatly increased by the presence of slash. If, on the other hand, a new slash area will be an extension of an existing one, danger of spreading wildfire will be increased materially. Cutting units often are selected to avoid creating large continuous areas of logging slash.

The principle of avoiding large areas of continuous slash applies also to precommercial thinning areas. Usually they are broken up into small enough units that wildfire soon will hit a fuel break where it can be controlled.

Broadcast burning in coastal forests may be done in the spring, summer, or autumn, most being done in the autumn during the drying period after rain. Then the logging slash and duff exposed on a clearcut may be dry enough to carry the fire while the residues under surrounding timber tend to remain too wet to burn. The larger fuels on the cutover usually are still dry inside from the summer drought and tend to be consumed more than during a spring burn. Also, in autumn there is less risk of dry weather following the fire than would be the case in the spring. Often there is the prospect of rain within a few days, thus minimizing risk of holdover fires.

Burning in spring is less common than in summer because many areas remain too wet to burn. Where burning can be accomplished, the fire consumes mostly fine material. Some recent increases in spring burning have resulted from smoke management restrictions delaying autumn burning, so the treatment is applied the following spring. Smoke management restrictions also have provided some emphasis for summer burning which, until recently, has been restricted mostly to wet areas with red alder residues. There are only limited periods when the westerly flow of air stops long enough to avoid smoke being carried inland over population centers, and these are more common in the summer. Spring and summer burns should be thoroughly mopped up to prevent fire escape during subsequent dry weather.

Fuel moisture is one of the most important factors in the timing of slash burning. If fuels are too wet, time will be wasted in getting the fire to burn and smoke will be increased. The resulting reduction in fire hazard may be inadequate, increasing the risk of a reburn. If fuels are too dry, the fire may burn too hot, damage the site, and spread to other areas.

Fuel-moisture indicator sticks may be used to indicate when burning conditions are favorable (Morris 1953, 1958a, 1958b, 1966). Ideal timing of a burn must be tempered with air quality requirements, and burning must be restricted to days when smoke will not be carried over population centers or recreational areas. Burning may be delayed until a later date, or until another year. However, rapid growth of vegetation on most coastal sites precludes burning after a year's delay unless a preburn spray is applied.

Firelines are constructed around most slash areas in advance of burning. Water often is made available for the more dangerous parts of the perimeter, and organic materials immediately outside the fireline are wetted down before ignition. Ignition often is started along the upper perimeter of the area, and a strip is burned out. As this fire dies down, the burned strip becomes, in effect, a widened fireline. Fire then is set progressively downhill to the lower edge of

the unit. There are many variations, depending on wind, topography, and other local conditions. The various techniques used for burning are described in detail by Brown and Davis (1973).

In general, fast and hot combustion of the fuel causes the least smoke emission and contributes to better dispersal by upper winds. Improved ignition systems have been developed for the rapid ignition required (Schimke et al. 1969).

Foresters in Oregon and Washington pioneered burning and related residue treatments for conversion of conifer sites currently dominated by red alder. This practice is increasingly common in these two States.

Generally in the Oregon and Washington hemlock-spruce, the trend is away from broadcast burning--to not burn at all or to restrict burning to the landing area and perhaps a few heavy slash concentrations. Major contributing factors are the moist climate, presence of advance regeneration, better utilization, more harvest cuttings in young stands that have little defect, and smoke management restrictions. There are, however, heavily decayed old-growth stands or open stands with dense brush understories where burning still appears to be a necessary treatment.

Residues management guidelines for public lands and for private lands for Oregon and Washington have been compiled by Pierovich et al. (1975).

BRITISH COLUMBIA

Residue management on all public and private forest land in British Columbia is prescribed by the British Columbia Forest Service after inspection of harvested areas (British Columbia Lumberman 1971). The B. C. Forest Service has prepared a guide to broadcast burning of logging slash where this treatment is prescribed (British Columbia Forest Service 1969). Currently, some areas are broadcast burned, some are left unburned, and on some only the residue concentrations are burned. It is the responsibility of the operator to carry out the prescribed treatment. The area must be released by the Forest Service before adjacent timber may be logged. The prescription may require special measures to protect the soil, established seedlings, adjacent timber, or other property (British Columbia Lumberman 1969). Snag felling is required as part of the hazard reduction program. Timber operators may elect to burn additional areas to improve access for planting or expose more mineral soil seed bed. Part of the road network is maintained after slash abatement to provide ready access in case of wildfire.

There has been a general reduction in fire danger in British Columbia in recent years, mostly due to better utilization. Contributing factors include conversion from steam to gas or diesel power, from rail to truck haul, and from lumber only to a lumber-plus-pulp economy. Snag felling has been made compulsory. Logging operations are closed during critical fire weather, better weather forecasts are available, and training and equipment for firefighting are better (British Columbia Lumberman 1969). Beginning January 1, 1966, the British Columbia Forest Service initiated a "Close Utilization Policy" providing a financial incentive for better utilization. In coastal forests, wood volume between 9.1-inch (23-cm) d.b.h. to a 6-inch (15-cm) top and 13.1-inch (33-cm) d.b.h. to an 8-inch (20-cm) top was sold for 55 cents per 100 cubic feet (2.8 m^3). These changes and increasing public pressure against smoke in the atmosphere are resulting in a

trend away from residue management by burning. The consensus of Canadian Forest Industries in 1971 was that about 30 percent of slash areas should be burned, although at that time the B.C. Forest Service was requiring about 50 percent (British Columbia Lumberman 1971).

ALASKA

In coastal Alaska, some 99 percent of commercial forest land is administered by the U.S. Forest Service or State of Alaska, the remainder being in small private ownerships. Logging residues on all forest lands are left essentially untreated.

Fire danger is usually low because of the cool, moist climate; and experience since pulp logging began in 1953 has shown the risk of wildfire in slash is not great enough to require treatment to reduce the hazard. Present Forest Service regulations limit the size of clearcuts to 160 acres (65 ha). This disperses the slash hazard and reduces the probability of large fires.

Operators are required to maintain fire equipment on logging operations at all times and, during occasional brief summer dry periods, may be required to alter working hours or suspend operations. Snag felling is required on National Forest lands.

Most of the timber logged in coastal Alaska is overmature, and defect is often high. This results in large accumulations of residue. Public concern is largely over esthetics and the apparent waste of raw material. Forest managers are also concerned over the obstruction caused by large residue to future management of young stands. Utilization standards continue to improve, and more defective material is used for pulp. There may be some limited need for burning in the future, but the present trend toward better utilization and no burning appears likely to continue for some time.

CONCLUSIONS AND RECOMMENDATIONS

Forest residue is receiving increased attention from land managers, and there is increasing interest by the general public. These are favorable trends which surely will continue. The result will be increasingly better residue management decisions. Decisions for treating residue or leaving it untreated should be based not only on short-term effects during the logging slash period but also on long-term effects on the ecosystem and the next rotation. A major objective is to maintain a viable forest ecosystem that will produce the desired balance of goods and services. The potential long-term productivity of a site must be maintained or improved, including the air and ground water resource, the fish and wildlife habitat, and the natural beauty of the area. There must be an adequate cover of organic material to protect the mineral soil from surface erosion.

Residue management decisions are made best as part of overall management planning and by consultation with experts in several fields. Single-purpose treatments usually should be avoided. Pierovich and Smith (1973) developed a framework for determination of the optimal residue treatment which essentially portrays the thought processes that might be followed in making a decision. Their model can be used for analyzing alternatives on relative scales, or it can be translated into operational forms for handling large masses of data in a

computer. Jemison and Lowden (1974) point out that different areas have a different mix of important environmental factors, and different landowners have different land-use objectives. They suggest establishing environmental goals for each area requiring a residue treatment decision, then listing the desirable and undesirable effects of each treatment alternative. Alternatives are evaluated in light of their costs and benefits before treatment decisions are made.

Blanket rules often do not apply. The same residue volume may be an essential part of the ecosystem in one area and require almost complete disposal in another, An independent decision should be made for each.

A caution to keep in mind in Oregon and Washington is a tendency to extend Douglas-fir silviculture, including residue management, westward into the more moist coastal strip. This tendency should be avoided and the hemlock-spruce type recognized as a separate entity with different residue management problems.

A basic solution to the residue problem is improved utilization--improvement to the point that residue treatment for hazard reduction is unnecessary. Much progress has been made--logs are now being removed down to a 6-inch (15-cm) and often smaller top diameter.

An increasing percent of total harvest is in young age classes with little defect. Extension of road systems permits salvage logging over increasingly larger areas; so fewer residues accumulate. The trend toward less residue volume is likely to continue as increasing demand for wood fiber permits utilization of smaller and more defective material. Whole-tree chipping is a rapidly increasing practice in small timber (Wallace 1974). Pulping the complete tree including limbs and stump, complete use of logging residues as fuel, and chemical extraction are definite possibilities (Lowe 1973, Grantham et al. 1974, Schofield 1960). For the near term, the costs of handling and processing residues in comparison with long-established sources of fiber will limit utilization. However, in the final analysis, utilization probably will be limited, not by economics but by the need to maintain the nutrient capital and soil stability of the site. Additional research to determine minimum residue levels is needed. In the interim, we feel that leaving the duff plus the needles, twigs, and branches from the logging residue should be adequate on most sites (fig. 19).

The forest manager and, in many cases, also the concerned government forester should decide, in advance of logging, the most desirable postlogging environment for each area to be harvested. The harvesting operation and any followup residue treatments should be designed to provide this environment. It is important that decisions be made and treatments, if any, applied promptly. Hemlock-spruce ecosystems change rapidly and a treatment planned for one season may not be appropriate if delayed until the next.

Usually, first consideration is the fire hazard--is slash burning or other treatment needed to reduce the hazard? Will added protection suffice? Is any action needed at all? Generally in southern areas, experienced and efficient fire control organizations have crews on standby in the hemlock-spruce or adjacent Douglas-fir type. Here, greatest reductions in damage from wildfire probably will come not from increasing the protection organization but from reducing the fire hazard. Particularly important is the development of fuel breaks to provide strategic and safe places where firelines can be quickly established.

Figure 19.--Leaving the duff of the forest floor plus leaves, twigs, and branches of the logging residue should maintain adequate nutrient levels on most sites. Divisions on stake indicate 1 foot (30 cm).

Strong arguments for burning develop when there are large residue accumulations, an expectation of dry weather, and accompanying risk of ignition--the high fire danger situation. This is most common in the southern portion of the range. A prescription for burning based largely on residue accumulations probably will be a one-time prescription, because large fuel accumulations will be unlikely in the future.

Strong arguments against burning develop in the opposite situation where fire danger is low. The obvious example is Alaska where harvested areas rarely dry out enough to burn. Residue volumes, however, are high and will continue high until the old-growth timber is harvested and the residues there have time to decay and become incorporated into the soil. In Oregon and Washington, advocates of nonburning often are managing healthy young stands in areas where economic conditions facilitate good utilization. They may be able to exclude the public during periods of high fire danger. They often plan to utilize advance regeneration present on harvested areas.

These arguments for and against burning eventually may be resolved in favor of nonburning as improved techniques and economic conditions permit improved utilization of small logs and defective material. Forest land managers should strive for utilization that will avoid the need for the costly, sometimes risky, residue treatments now essential on some harvested areas.

The ecological relationships between residues and seedling establishment should be used to control seedling density and species composition of the new

timber stand. Fresh residues are poor seed beds. Residue management should leave them distributed so as to provide the desired number of mineral soil seed beds or planting sites, covering all others to prevent overstocking. Where advance regeneration is prolific and intermixed with logging residues, treatments should destroy enough seedlings to reduce stocking to the desired level. Where Douglas-fir is desired, treatments should expose mineral soil planting sites or seed beds. Shade provided by residues can aid seedling establishment during dry summers.

There are several situations where individual factors carry heavy weight in making residue management decisions:

1. Protect the soil resource. Soils with high erosion potential need to be protected by a mantle of forest floor material or logging residues. Broadcast burning and tractor piling of slash should be avoided in such areas. Yarding of logs and, where appropriate, YUM should be accomplished by lifting logs free of the ground. Lopping and scattering of residues and special fire protection measures are preferred alternatives to treatments that would expose mineral soil.

2. Protect the nutrient capital. On nutrient-deficient forest soils and soils low in clays or organic matter, the nutrient capital stored in forest residues, particularly the forest floor, is needed for tree nutrition. Only large residues should be removed from these areas, and the forest floor should not be reduced by burning. The desired volume and arrangement of residues to be left on the site should be identified and the harvesting operation and residue treatments planned accordingly. More information is needed on how much organic material should be left. In the interim, we feel that leaving the duff plus needles, twigs, and branches from the logging residue should be adequate for most sites.

3. Protect the stream channels. Timber should not be felled across streams used for fish spawning or rearing. Residues that are imbedded in stream channels or streambanks and are not blocking fish migration or causing channel erosion should be left undisturbed. Residues that may be picked up by high water and cause downstream damage and those that occupy fish rearing space should be carefully removed from stream channels, preferably during the low-water period, and placed above high-water mark or otherwise disposed of. Cleaning should be done by hand where necessary to reduce damage to streambanks. Riparian vegetation should be left to shade the stream surface and serve as a barrier for surface movement of soil toward the stream. Stream cleaning should be done under supervision of an experienced fisheries biologist.

4. Protect intermixed seedlings. When desirable tree seedlings are intermixed with logging residues, broadcast burning should be avoided. Alternative treatments include piling and burning, lopping and scattering, YUM, and providing extra fire protection. Often it will be possible to destroy numerous trees and still leave a full stocking of well-distributed seedlings. If stocking is incomplete, site preparation should be incorporated into the residue treatment with the objective of preparing appropriate seed beds for natural or artificial regeneration.

5. Control vegetative competition. Some stands in Oregon and Washington have a heavy brush understory which, after harvest cutting, remains intermixed with logging residues. Broadcast burning may be appropriate here to control brush,

reduce fire hazard, and open up the area for seedling establishment. An approved preburn herbicide spray may be needed. Burning should be followed by prompt plantation establishment and followup treatments with approved herbicides as needed to keep seedlings ahead of sprouting brush plants.

6. Control dwarf mistletoe. Mistletoe-infested seedlings should be classed as forest residues and destroyed by broadcast burning or other methods as part of disease control programs.

7. Maintain recreation and scenic areas. Special attention should be given to residue management in recreation and scenic areas. When accumulation of residues is unavoidable, prompt action, within cost limitations, should be taken to improve the appearance of the area. Particularly important are areas close to public travel. Residues which are obviously man caused and do not blend with the landscape should be disposed of. If chipping is used, chips should be distributed well, avoiding piles that will be apparent to the public and take a long time to decay. If burning is used, charred remains such as partly consumed logs, burn piles, and scorched trees should be avoided.

8. Avoid continuous areas of logging residues. Creating large areas of continuous logging residues unnecessarily increases fire hazard and should be avoided. This problem is confined mostly to the southern portion of the hemlock-spruce range. Precommercial and commercial thinnings also should be planned to avoid large, continuous slash. If thinning is done in the fall, needles will have fallen off the branches before the next fire season.

9. Change the timber type. If seral species such as Douglas-fir are desired, residue treatment by burning often is indicated. Burning is less expensive than most other treatments. It will destroy much of the advance regeneration of shade-tolerant species and open up the area for seeding and planting, or natural seed fall of desired species. Concurrently, it will reduce the fire hazard.

10. Follow smoke management plans. When residue concentrations are near smoke-sensitive areas and there is a history of wildfire, residue reduction by prescribed burning often is a better alternative than accepting the risks of wildfire. Burning should be accomplished when smoke will flow away from the sensitive area or be carried far aloft by strong convection currents. Local smoke management plans should be followed. A fast, hot fire followed by prompt mopup is desirable.

11. Treat large residue volumes. Residue treatments are needed when residue volume is so great that it will interfere with seedling establishment and intensive management of the new stand. Intensive management programs are more advanced in the southern portion of the range and this is where residues are more likely to be a serious fire hazard. The most appropriate treatments are broadcast burning and YUM. Treatments should be designed to leave an adequate number of partially shaded mineral soil seed beds available for natural regeneration, seeding, or planting.

In general, the trend away from broadcast burning is likely to continue. Unlike Douglas-fir and pine, hemlock and spruce have not depended on fire for their perpetuation, and fire or similar disturbance need not be an integral part of their ecology. Fire should not be eliminated but should be retained as a management alternative and used when the benefits outweigh the detriments.

Additional research is needed to expand the scientific base for residue management. Research needs for the Pacific Northwest are listed in detail by Cramer (1974); here we emphasize only three needs of particular import in hemlock-spruce.

Long-term nutritional aspects of residues need further study. Economics of forest utilization may soon make profitable the removal of organic material better left on the site as part of the nutrient capital. This point already may have been reached in some hemlock-spruce areas. We need to know what is needed to nurture the new crop. May some of it be removed and replaced by fertilization? In short, what are the trade offs between utilization of organic material and site productivity? In southern hemlock-spruce areas, the alternative of fire and its short- and long-term effects also enter this picture.

Esthetic aspects of residue management also need study. Hemlock-spruce forests receive high recreation use. Most of this is water oriented with people congregating on the beaches or in the estuaries, or traveling by boat along sheltered waterways. The general public, then, sees most harvest cuttings from a distance. How residue management affects the appearance of an area and public reaction to it needs to be determined and considered in decisionmaking.

Protection and improvement of fish habitat are particularly important in coastal forests, and more knowledge is needed on effects of residues and residue treatments. Brush and other live residues are a problem on many areas. Often they can be controlled with herbicides, but we need herbicides that do not contaminate the aquatic environment.

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Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key--out of the reach of children and animals--and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

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Use Pesticides Safely

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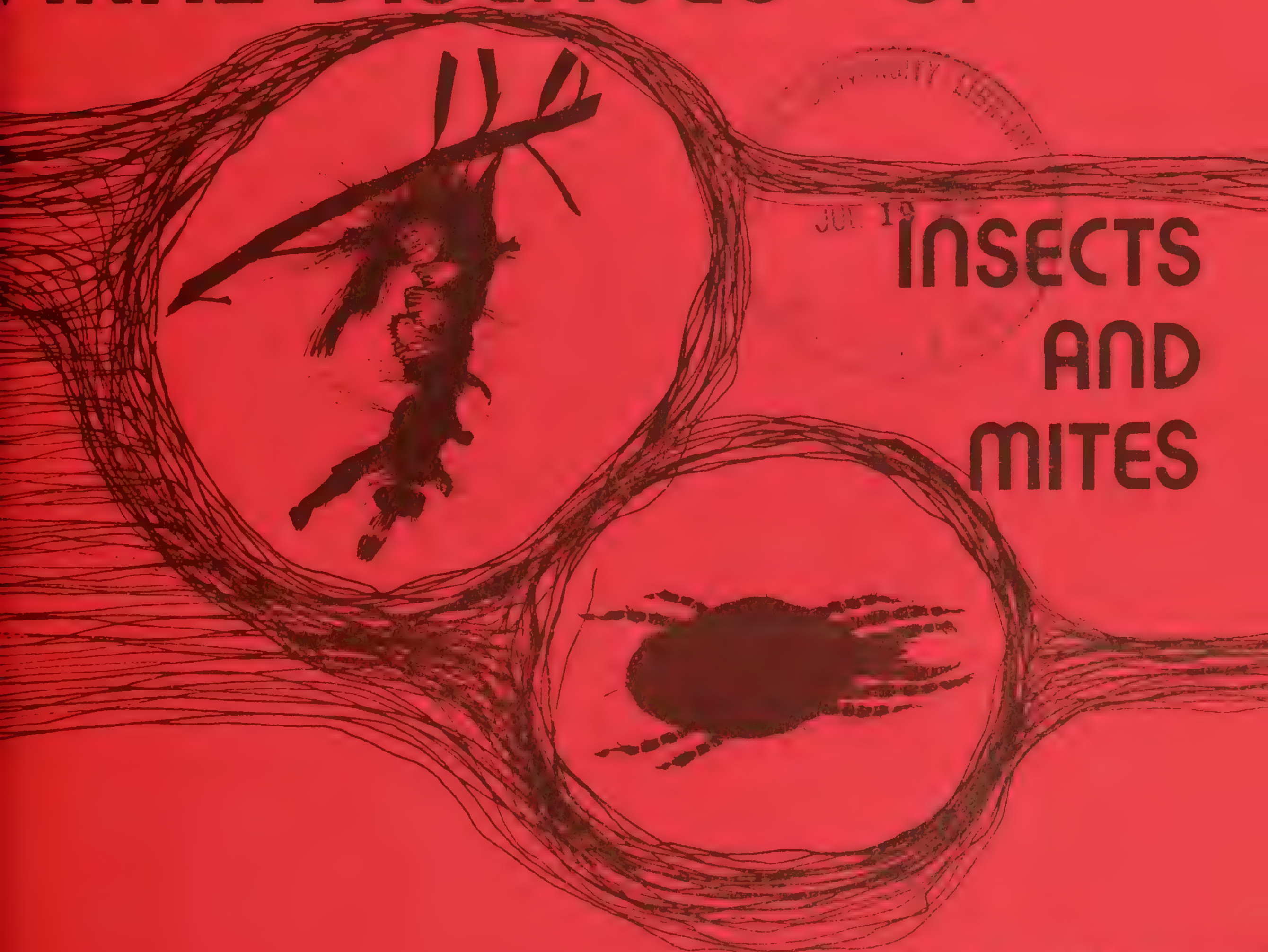
A CATALOG OF VIRAL DISEASES OF INSECTS AND MITES



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Mauro E. Martignoni
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PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
PORTLAND, OREGON

ABSTRACT

This comprehensive catalog of viral diseases of two large groups of arthropods updates the previous surveys of the world's literature published by Hughes in 1957 and by Martignoni and Langston in 1960. This computer-based catalog lists over 600 species of insects and mites, each reported to have one or more of 21 viral diseases or disease groups, for a total of over 900 host-virus records. The catalog consists of two lists. In the first one the hosts are listed in taxonomic sequence (order, family, genus, species). Species appear alphabetically within each genus, genera alphabetically within each family, and families alphabetically within each order. In the second list, the hosts are listed alphabetically by specific names, without consideration of the higher taxa. The host-virus records are stored on computer tape; additions and corrections to the master file can be made easily, and thus the catalog can be revised without much effort.

Keywords: Virus (-insecta, mites, computerized virus catalog.

INTRODUCTION

This comprehensive catalog of insects and mites reported to have viral diseases is an example of the kind of documentation one can generate from the computer-assisted information system established at the Forestry Sciences Laboratory in 1970 (Martignoni et al. 1973). The uniqueness of this Catalog lies in its coverage: this Catalog does not only add to, but it also includes viral diseases and species of arthropods previously cataloged in the "Annotated List" published by Hughes (1957) and in its "Supplement" published by Martignoni and Langston (1960). The present Catalog results from our analysis of the information content of 2, 300 publications (as of this writing). Of these, 733 formed the basis for the lists published by Hughes (1957) and by Martignoni and Langston (1960). It should be emphasized that those two lists, as well as the present Catalog, are not the result of simple title scans, but rather they were generated from a thorough analysis of each article entered in our master file. The methods of input analysis and preparation have been described by Martignoni et al. (1973). The techniques of information storage and retrieval are those of the eight FAMULUS program subsystems described by Burton et al. (1969) and outlined, in greater detail, in the "FAMULUS User's Manual" (National Technical Information Service 1969).

After completion of the guidelines for the FAMULUS version of the Catalog of Viral Diseases (Martignoni et al. 1973), we decided to develop a cost-saving set of computer routines which would list in a condensed and easily readable format all host-virus records in our master files (which also include the records published by Hughes 1957 and by Martignoni and Langston 1960). This was achieved with the cooperation of the Biometrics Service of our Experiment Station. This set of routines sorts and lists species of insects and mites, along with their viral diseases (as code numbers), in four separate printouts:

(1) The species are listed alphabetically, by specific names; if one species has one or more subspecies, these are listed, too, in alphabetical sequence. This list serves as a general host index by specific names, and it disregards arrangement of the species by higher taxonomic categories.

(2) The genera are listed in alphabetical sequence; species and subspecies are listed alphabetically within each genus.

(3) The families are listed in alphabetical sequence; the genera are listed alphabetically within each family, as well as the species and subspecies within each genus.

(4) The orders are listed in alphabetical sequence; the families and each subsequent lower-rank taxon are listed alphabetically.

Printouts 1 and 4 are reproduced here (appendixes).

Updating these lists requires a minimal effort only, once the appropriate information has been retrieved from specialized literature and entered into the FAMULUS master file. The processing cost for these four printouts is insignificant (less than $3, as of this writing). Thus, updated printouts can be obtained whenever new host records or new disease records are added to the master tapes.

Our Catalog of Viral Diseases uses the currently accepted scientific names of host species. Recent monographs and several specialists were consulted to determine current and correct specific,

generic, and family designations. The disease names (see key) are those most commonly used in the English language. Their definitions can be found in the "Abridged Glossary" (Steinhaus and Martignoni 1970), with the exception of "crystalline-array virosis" and of "hairless-black syndrome," two terms only recently added to the list of viral diseases of insects and mites. The selection of a disease name reflects the information content of each publication. For instance, POLYHEDROSIS (code 16) indicates that the author of a report did not specify whether the disease was a NUCLEOPOLYHEDROSIS (code 12) or a CYTOPLASMIC POLYHEDROSIS (code 5). In the majority of cases, viral diseases have been reported as naturally occurring in their hosts ("natural hosts" or "typical hosts"). In a few cases, however, the reports indicate that the disease resulted from inoculation with a virus originally isolated from another host. Thus, some of the records in the following list represent "accidental hosts," i.e., hosts in which the pathogen is not commonly found, nevertheless hosts susceptible to infection with that pathogen. These few instances have not been marked in the present lists; thus it is not possible to identify accidental hosts. However, information on host specificity (or host range) of the pathogens is contained in the master file.

A rather disturbing situation has arisen in recent years (especially since ultramicrotomes and electron microscopes are no longer restricted to a few privileged laboratories), one that forced us to lump several records in the broad and ill-defined category PRESUMED VIROSIS (code 17). In our opinion, far too many manuscripts are rushed to the publisher before sufficient evidence has been obtained on the viral nature and pathogenicity of "virus-like" particles discovered in ultrathin sections. In several instances, the viral nature of these particles is only a conjecture. Faced with the dilemma of ignoring such records, or of listing them, we decided for the latter option, with the hope that, eventually, the viral nature of the particles would be confirmed in further studies. In the meantime, the reader should consider each code 17 entry with moderate skepticism.

As the number of reports dealing with viral diseases of insects and mites has been increasing at an accelerated rate since about 1960, publication of a comprehensive list of literature citations in a conventional format is now beyond the scope of this Catalog. The printing cost alone, for such an extensive bibliography, would be prohibitive. Those interested in literature citations can find useful bibliographies in several publications, in addition to those prepared by Hughes (1957) and by Martignoni and Langston (1960). For instance, the literature relating to the nucleopolyhedrosis viruses was reviewed by Bergold (1963), the cytoplasmic polyhedrosis viruses by Smith (1963) and by Aruga and Tanada (1971), the granulosis viruses by Huger (1963), and the viruses pathogenic for the honey bee by Bailey (1963). There are also bibliographies covering the viral diseases of insects and mites in selected geographical areas (e.g., Gershenson 1960 Hukuhara et al. 1966, Smirnoff and Juneau 1973). Finally, for those interested in obtaining one or more virus isolates (from a list of 223 viruses), the catalog by van der Geest and van der Laan (1971) may prove very convenient, as it includes also a list of addresses of individuals or laboratories willing to supply the samples.

The data base for the present Catalog is preserved in a master file (on magnetic tape and on paper) at our Station. We emphasize that the data base consists only of published host records. Unpublished host records (material stored in virus collections, restricted laboratory reports, and personal correspondence) do not appear in the Catalog.

USE OF THE CATALOG

This Catalog of Viral Diseases consists of two lists, much in the same way as the two previous catalogs (Hughes 1957, Martignoni and Langston 1960). The first (app. 1) is a list of hosts, arranged alphabetically by orders, by families (alphabetically within each order), by genera (alphabetically within each family), and by species (alphabetically within each genus)--and subspecies where appropriate. Each host record is followed by one or more disease code numbers. A key to the codes is available (p. 35) and it can be unfolded to the right side of the pamphlet for convenience.

The second list (app. 2) is an index to hosts by their specific names (trivial names). These names are listed in alphabetical order, regardless of superspecific categories. Unlike indexes in the two previously published catalogs, this index also contains the names of the higher taxa (genus, family, and order) as well as the disease codes, printed on the same line as the specific name. Thus, in this catalog, the index is a guide to hosts listed alphabetically, by their specific names, and at the same time a complete catalog, containing information on taxonomy as well as on pathology.

Both lists (by taxonomic categories and by specific names) are generated simultaneously by the computer, from a single input. We can thus avoid discrepancies between the two lists.

A search for a particular host would not be considered complete unless the synonyms of the generic and specific names were also included in that search. Unfortunately, it would be a Sisyphean task, beyond the scope of our Catalog, to list all synonyms of each host species. However, in table 1 we list some of the most common synonyms (those most frequently encountered in the literature dealing with viral diseases) along with the accepted scientific names of arthropods concerned. Additional synonyms can be found in specialized monographs. Table 1 and, if desirable, such specialized monographs should be consulted before a Catalog search for a given insect or mite species is abandoned.

ACKNOWLEDGMENTS — AND A PLEA FOR ASSISTANCE

The helpful and patient staff of the Biometrics Section of the Pacific Northwest Forest and Range Experiment Station contributed to the preparation of the sorting routines and to the updating of the master file through FAMULUS. We are much indebted to our dedicated colleagues.

We are also grateful to those authors who, for many years, have supplied us with reprints of their publications on viral diseases of insects and mites. We trust that their important contribution to the Catalog of Viral Diseases will continue.

We ask those who are interested in the maintenance of this Catalog and who may have noticed errors and missing host records to assist us by completing and mailing to us one or more of the input sheets (inserted at the end of this pamphlet) or by writing us (in the case of corrections and suggestions).[1] If we missed host records, we would also appreciate receiving one reprint of each pertinent publication, for such reprints enable us to complete the necessary analysis of the information content of the publication.

1/ Send forms to authors, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon 97331.

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APPENDIX 1

List of Hosts by Taxonomic Categories

ORDER	FAMILY	GENUS	SPECIES	DISEASES
ACARINA	TETRANYCHIDAE	PANONYCHUS	CITRI	13 17
ACARINA	TETRANYCHIDAE	PANONYCHUS	ULMI	13
ACARINA	TETRANYCHIDAE	TETRANYCHUS	CINNABARINUS	13 17
ACARINA	TETRANYCHIDAE	TETRANYCHUS	MULTISETIS	17
ACARINA	TETRANYCHIDAE	TETRANYCHUS	TELARIUS	17
COLEOPTERA	BUPRESTIDAE	AGRILUS	SUVOROVI POPULNEUS	5
COLEOPTERA	BUPRESTIDAE	MELANOPHILA	PICTA	5 16
COLEOPTERA	CERAMBYCIDAE	BATOCERA	LINEOLATA	12
COLEOPTERA	CURCULIONIDAE	ANTHONOMUS	GRANDIS	10 12
COLEOPTERA	DERMESTIDAE	ANTHRENUS	MUSEORUM	12 16
COLEOPTERA	DERMESTIDAE	DERMESTES	LARDARIUS	12 16
COLEOPTERA	GYRINIDAE	GYRINUS	NATATOR	13
COLEOPTERA	LUCANIDAE	FIGULUS	SUBLAEVIS	19
COLEOPTERA	SCARABAEIDAE	AMPHIMALLON	SOLSTITIALIS	19
COLEOPTERA	SCARABAEIDAE	ANOPLOGNATHUS	POROSUS	19
COLEOPTERA	SCARABAEIDAE	ANOXIA	VILLOSA	19
COLEOPTERA	SCARABAEIDAE	APHODIUS	TASMANIAE	13 19
COLEOPTERA	SCARABAEIDAE	COSTELYTRA	ZEALANDICA	10
COLEOPTERA	SCARABAEIDAE	DASYGNATHUS	SP.	19
COLEOPTERA	SCARABAEIDAE	DEMODENA	BORANENSIS	19
COLEOPTERA	SCARABAEIDAE	DERMOLEPIDA	ALBOHIRTUM	19
COLEOPTERA	SCARABAEIDAE	GEOTRUPES	SILVATICUS	19
COLEOPTERA	SCARABAEIDAE	GEOTRUPES	STERCOROSUS	19
COLEOPTERA	SCARABAEIDAE	HETERONYCHUS	ARATOR	13
COLEOPTERA	SCARABAEIDAE	MELOLONTHA	HIPPOCASTANI	20
COLEOPTERA	SCARABAEIDAE	MELOLONTHA	MELOLONTHA	6 19 20
COLEOPTERA	SCARABAEIDAE	OPOGONIA	SP.	10
COLEOPTERA	SCARABAEIDAE	ORYCTES	BOAS	20
COLEOPTERA	SCARABAEIDAE	ORYCTES	MONOCEROS	20
COLEOPTERA	SCARABAEIDAE	ORYCTES	NASICORNIS	11 20
COLEOPTERA	SCARABAEIDAE	ORYCTES	RHINOCEROS	11
COLEOPTERA	SCARABAEIDAE	OTHNONIUS	BATESI	19
COLEOPTERA	SCARABAEIDAE	PERICOPTUS	TRUNCATUS	13
COLEOPTERA	SCARABAEIDAE	PHYLLOPERTHA	HORTICOLA	19
COLEOPTERA	SCARABAEIDAE	PHYLLOPHAGA	PLEEI	19
COLEOPTERA	SCARABAEIDAE	RHOPAEA	VERRAUXI	19
COLEOPTERA	SCARABAEIDAE	SCAPANES	AUSTRALIS GROSSEPUNCTATUS	11
COLEOPTERA	SCARABAEIDAE	SERICESTHIS	PRUINOSA	10
COLEOPTERA	TENEBRIONIDAE	TENEBRIO	MOLITOR	10 17
DIPTERA	BIBIONIDAE	BIBIO	MARCI	10
DIPTERA	CALLIPHORIDAE	CALLIPHORA	VOMITORIA	10 12 16
DIPTERA	CHAOBORIDAE	CORETHRELLA	APPENDICULATA	10
DIPTERA	CHAOBORIDAE	CORETHRELLA	BRAKELEYI	10
DIPTERA	CHIRONOMIDAE	CHIRONOMUS	ATTENUATUS	19
DIPTERA	CHIRONOMIDAE	CHIRONOMUS	LURIDUS	19
DIPTERA	CHIRONOMIDAE	CHIRONOMUS	PLUMOSUS	5 10
DIPTERA	CHIRONOMIDAE	CHIRONOMUS	TENTANS	12 17 19
DIPTERA	CHIRONOMIDAE	GOELDICHIRONOMUS	HOLOPRASINUS	5 17 19
DIPTERA	COELOPIDAE	COELOPA	FRIGIDA	17
DIPTERA	CULICIDAE	AEDES	AEGYPTI	5 10 12 17
DIPTERA	CULICIDAE	AEDES	ANNULIPES	10
DIPTERA	CULICIDAE	AEDES	CANTANS	10
DIPTERA	CULICIDAE	AEDES	DETRITUS	10
DIPTERA	CULICIDAE	AEDES	DORSALIS	10
DIPTERA	CULICIDAE	AEDES	FULVUS PALLENS	10
DIPTERA	CULICIDAE	AEDES	NIGROMACULIS	12
DIPTERA	CULICIDAE	AEDES	SIERRENSIS	10 12
DIPTERA	CULICIDAE	AEDES	SOLLICITANS	5 10 12
DIPTERA	CULICIDAE	AEDES	STICTICUS	10
DIPTERA	CULICIDAE	AEDES	STIMULANS	10
DIPTERA	CULICIDAE	AEDES	TAENIORHYNCHUS	5 10 12 13
DIPTERA	CULICIDAE	AEDES	TORMENTOR	12
DIPTERA	CULICIDAE	AEDES	TRISERIATUS	12 17
DIPTERA	CULICIDAE	AEDES	VEXANS	10
DIPTERA	CULICIDAE	ANOPHELES	ALBIMANUS	10 19
DIPTERA	CULICIDAE	ANOPHELES	CRUCIANS	12
DIPTERA	CULICIDAE	ANOPHELES	FREEBORNI	12
DIPTERA	CULICIDAE	ANOPHELES	QUADRIMACULATUS	10 14
DIPTERA	CULICIDAE	ANOPHELES	STEPHENSI	3 5
DIPTERA	CULICIDAE	ANOPHELES	SUBPICTUS	17
DIPTERA	CULICIDAE	CULEX	PECCATOR	10
DIPTERA	CULICIDAE	CULEX	PIPIENS	3
DIPTERA	CULICIDAE	CULEX	PIPIENS QUINQUEFASCIATUS	12
DIPTERA	CULICIDAE	CULEX	RESTUANS	17
DIPTERA	CULICIDAE	CULEX	SALINARIUS	5 10 12
DIPTERA	CULICIDAE	CULEX	TARSALIS	5 12 13
DIPTERA	CULICIDAE	CULEX	TERRITANS	5 10 17
DIPTERA	CULICIDAE	CULISETA	INORNATA	10
DIPTERA	CULICIDAE	CULISETA	MELANURA	5 10
DIPTERA	CULICIDAE	ORTHOPODOMYIA	SIGNIFERA	17

ORDER	FAMILY	GENUS	SPECIES	DISEASES
DIPTERA	CULICIDAE	PSOROPHORA	CONFINNIS	10 12 17
DIPTERA	CULICIDAE	PSOROPHORA	FEROX	5 10 12
DIPTERA	CULICIDAE	PSOROPHORA	HORRIDA	10
DIPTERA	CULICIDAE	PSOROPHORA	VARIPES	10 12
DIPTERA	CULICIDAE	URANOTAENIA	SAPPHIRINA	12 17
DIPTERA	CULICIDAE	WYEOMYIA	SMITHII	12
DIPTERA	DROSOPHILIDAE	DROSOPHILA	AFFINIS	3
DIPTERA	DROSOPHILIDAE	DROSOPHILA	ANANASSAE	13
DIPTERA	DROSOPHILIDAE	DROSOPHILA	BIFASCIATA	17
DIPTERA	DROSOPHILIDAE	DROSOPHILA	IMMIGRANS	3 13
DIPTERA	DROSOPHILIDAE	DROSOPHILA	MELANOGASTER	3 13 17
DIPTERA	DROSOPHILIDAE	DROSOPHILA	MONTIUM	13
DIPTERA	DROSOPHILIDAE	DROSOPHILA	PAULISTORUM	17
DIPTERA	DROSOPHILIDAE	DROSOPHILA	PSEUDOOBSCURA	17
DIPTERA	DROSOPHILIDAE	DROSOPHILA	VIRILIS	17
DIPTERA	DROSOPHILIDAE	DROSOPHILA	WILLISTONI	17
DIPTERA	ITONIDIDAE	CONTARINIA	TRITICI	16
DIPTERA	ITONIDIDAE	SITODIPLOSIS	MOSELLANA	16
DIPTERA	MUSCIDAE	GLOSSINA	FUSCIPES FUSCIPES	17
DIPTERA	MUSCIDAE	GLOSSINA	MORSITANS CENTRALIS	17
DIPTERA	MUSCIDAE	MUSCA	DOMESTICA	3
DIPTERA	SCIARIDAE	RHYNCHOSCIARA	ANGELAE	12 17
DIPTERA	SCIARIDAE	RHYNCHOSCIARA	HOLLAENDERI	12
DIPTERA	SCIARIDAE	RHYNCHOSCIARA	MILLERI	12
DIPTERA	SIMULIIDAE	CNEPHIA	MUTATA	5
DIPTERA	SIMULIIDAE	PROSIMULIUM	MIXTUM	5
DIPTERA	SIMULIIDAE	SIMULIUM	ORNATUM	10
DIPTERA	TACHINIDAE	UGYMYIA	SERICARIAE	12
DIPTERA	TEPHRITIDAE	CERATITIS	CAPITATA	3
DIPTERA	TIPULIDAE	TIPULA	LIVIDA	10
DIPTERA	TIPULIDAE	TIPULA	OLERACEA	10
DIPTERA	TIPULIDAE	TIPULA	PALUDOSA	10 12 16
HEMIPTERA	APHIDIDAE	RHOPALOSIPHUM	MAIDIS	17
HEMIPTERA	CICADELLIDAE	COLLADONUS	MONTANUS	10
HEMIPTERA	CICADELLIDAE	NEPHOTETTIX	CINCTICEPS	10
HEMIPTERA	DELPHACIDAE	LAODELPHAX	STRIATELLA	10
HYMENOPTERA	APIDAE	APIS	MELLIFERA	1 2 6 10 13 15 17 18 21
HYMENOPTERA	ARGIDAE	ARGE	PECTORALIS	12
HYMENOPTERA	BOMBIDAE	BOMBUS	AGRORUM	1
HYMENOPTERA	BOMBIDAE	BOMBUS	HORTORUM	1
HYMENOPTERA	BOMBIDAE	BOMBUS	LUCORUM	1
HYMENOPTERA	BOMBIDAE	BOMBUS	RUDERARIS	1
HYMENOPTERA	BOMBIDAE	BOMBUS	TERRESTRIS	1
HYMENOPTERA	BRACONIDAE	CARDIOCHILES	NIGRICEPS	17
HYMENOPTERA	DIPRIONIDAE	DIPRION	HERCYNIAE	12
HYMENOPTERA	DIPRIONIDAE	DIPRION	NIPPONICA	12
HYMENOPTERA	DIPRIONIDAE	DIPRION	PALLIDA	12
HYMENOPTERA	DIPRIONIDAE	DIPRION	PINDROWI	12
HYMENOPTERA	DIPRIONIDAE	DIPRION	PINI	12
HYMENOPTERA	DIPRIONIDAE	DIPRION	POLYTOMA	12
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	ABIETIS	12 16
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	EXITANS	12
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	LECONTEI	12 16
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	MERKELI	5
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	MUNDUS	16
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	NANULUS	16
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	PRATTI BANKSIANAE	12
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	PRATTI PRATTI	16
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	SERTIFER	12 16 17
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	SWAINEI	12
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	TAEDAE LINEARIS	12
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	TAEDAE TAEDAE	12 16
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	VIRGINIANA	12
HYMENOPTERA	FORMICIDAE	FORMICA	LUGUBRIS	17
HYMENOPTERA	HALICTIDAE	NOMIA	MELANDERI	17
HYMENOPTERA	MEGACHILIDAE	MEGACHILE	ROTUNDATA	17
HYMENOPTERA	PAMPHILIIDAE	ACANTHOLYDA	NEMORALIS	16
HYMENOPTERA	PAMPHILIIDAE	CEPHALCIA	ABIETIS	16
HYMENOPTERA	PAMPHILIIDAE	CEPHALCIA	ALPINA	16
HYMENOPTERA	PAMPHILIIDAE	CEPHALCIA	ISSIKI	12
HYMENOPTERA	TENTHREDINIDAE	ANOPLONYX	DESTRUCTOR	5
HYMENOPTERA	TENTHREDINIDAE	NEMATUS	OLFACIENS	12
HYMENOPTERA	TENTHREDINIDAE	PRISTIPHORA	ERICHSONII	12 16
HYMENOPTERA	TENTHREDINIDAE	PRISTIPHORA	GENICULATA	12
HYMENOPTERA	TENTHREDINIDAE	TRICHIOCAMPUS	IRREGULARIS	12
HYMENOPTERA	TENTHREDINIDAE	TRICHIOCAMPUS	VIMINALIS	12
ISOPTERA	RHINOTERMITIDAE	COPTOTERMES	LACTEUS	17
ISOPTERA	TERMITIDAE	NASUTITERMES	EXITIOSUS	17
ISOPTERA	TERMOPSIDAE	POROTERMES	ADAMSONI	17
LEPIDOPTERA	AEGERIIDAE	BEMBECIA	CONTRACTA	5 12

ORDER	FAMILY	GENUS	SPECIES	DISEASES
LEPIDOPTERA	ANTHELIDAE	ANTHELA	VARIA	12
LEPIDOPTERA	ANTHELIDAE	PTEROLOCCERA	AMPLICORNIS	12
LEPIDOPTERA	ARCTIIDAE	AMSACTA	ALBISTRIGA	12
LEPIDOPTERA	ARCTIIDAE	AMSACTA	MOOREI	12 19
LEPIDOPTERA	ARCTIIDAE	APANTESIS	VIRGO	16
LEPIDOPTERA	ARCTIIDAE	ARCTIA	CAJA	5 12 16
LEPIDOPTERA	ARCTIIDAE	ARCTIA	VILLICA	5 12
LEPIDOPTERA	ARCTIIDAE	ARDICES	GLATIGNYI	12
LEPIDOPTERA	ARCTIIDAE	CYCNIA	MENDICA	5 12
LEPIDOPTERA	ARCTIIDAE	DIACRISIA	OBLIQUA	9
LEPIDOPTERA	ARCTIIDAE	DIACRISIA	PURPURATA	5 12
LEPIDOPTERA	ARCTIIDAE	DIACRISIA	VIRGINICA	12
LEPIDOPTERA	ARCTIIDAE	DIONYCHOPUS	AMASIS	9 13
LEPIDOPTERA	ARCTIIDAE	ECPANTHERIA	ICASIA	9 12
LEPIDOPTERA	ARCTIIDAE	ESTIGMENE	ACREA	5 9 12 16 19
LEPIDOPTERA	ARCTIIDAE	EUPLAGIA	QUADRIPUNCTARIA	5
LEPIDOPTERA	ARCTIIDAE	HALISIDOTA	ARGENTATA	12
LEPIDOPTERA	ARCTIIDAE	HALISIDOTA	CARYAE	12
LEPIDOPTERA	ARCTIIDAE	HYPHANTRIA	CUNEA	5 9 12 16
LEPIDOPTERA	ARCTIIDAE	HYPOCRITA	JACOBAEAE	5 12
LEPIDOPTERA	ARCTIIDAE	PANAXIA	DOMINULA	5 12
LEPIDOPTERA	ARCTIIDAE	PARASEMIA	PLANTAGINIS	5
LEPIDOPTERA	ARCTIIDAE	PERICALLIA	RICINI	9 12
LEPIDOPTERA	ARCTIIDAE	PHRAGMATOBIA	FULIGINOSA	5 9 16
LEPIDOPTERA	ARCTIIDAE	SPILARCTIA	SUBCARNEA	5 12
LEPIDOPTERA	ARCTIIDAE	SPILOSOMA	LUBRICIPEDA	5 12
LEPIDOPTERA	ARCTIIDAE	SPILOSOMA	LUTEA	5
LEPIDOPTERA	BOMBYCIDAE	BOMBYX	MORI	5 6 7 8 10 12 13 14 19
LEPIDOPTERA	BOMBYCIDAE	THEOPHILA	MANDARINA	5 12
LEPIDOPTERA	CARPOSINIDAE	CARPOSINA	NIPONENSIS	12
LEPIDOPTERA	COLEOPHORIDAE	COLEOPHORA	LARICELLA	12
LEPIDOPTERA	CRAMBIDAE	DIATRAEA	SACCHARALIS	9
LEPIDOPTERA	DANAIDAE	DANAUS	PLEXIPPUS	5 16
LEPIDOPTERA	DIOPTIDAE	PHRYGANIDIA	CALIFORNICA	12
LEPIDOPTERA	DREPANIDAE	DREPANA	LACERTINARIA	5
LEPIDOPTERA	EPIPASCHIIDAE	TETRALOPHA	SCORTEALIS	12 16
LEPIDOPTERA	GALLERIIDAE	CORCYRA	CEPHALONICA	12
LEPIDOPTERA	GALLERIIDAE	GALLERIA	MELLONELLA	5 6 10 12 13 16 19
LEPIDOPTERA	GELECHIIDAE	COLEOTECHNITES	MILLERI	9
LEPIDOPTERA	GELECHIIDAE	PECTINOPHORA	GOSSYPIELLA	5 12
LEPIDOPTERA	GELECHIIDAE	PHTHORIMAEA	OPERCULELLA	9 12
LEPIDOPTERA	GEOMETRIDAE	ABRAXAS	GROSSULARIATA	5 12
LEPIDOPTERA	GEOMETRIDAE	ALSOPHILA	POMETARIA	5 9 12
LEPIDOPTERA	GEOMETRIDAE	ANAITIS	PLAGIATA	5 12
LEPIDOPTERA	GEOMETRIDAE	ANTHELIA	HYPERBOREA	12
LEPIDOPTERA	GEOMETRIDAE	BISTON	BETULARIA	5
LEPIDOPTERA	GEOMETRIDAE	BISTON	HIRTARIA	12
LEPIDOPTERA	GEOMETRIDAE	BISTON	HISPIDARIA	12
LEPIDOPTERA	GEOMETRIDAE	BISTON	MARGINATA	16
LEPIDOPTERA	GEOMETRIDAE	BISTON	ROBUSTUM	12
LEPIDOPTERA	GEOMETRIDAE	BISTON	STRATARIA	12
LEPIDOPTERA	GEOMETRIDAE	BUPALUS	PINIARIUS	5 12 16
LEPIDOPTERA	GEOMETRIDAE	CARIPETA	DIVISATA	12
LEPIDOPTERA	GEOMETRIDAE	CLEORA	SECUNDARIA	17
LEPIDOPTERA	GEOMETRIDAE	CROCALLIS	ELINGUARIA	5
LEPIDOPTERA	GEOMETRIDAE	ECTROPIS	CREPUSCULARIA	16
LEPIDOPTERA	GEOMETRIDAE	ENNOMOS	QUERCARIA	12
LEPIDOPTERA	GEOMETRIDAE	ENNOMOS	QUERCINARIA	12
LEPIDOPTERA	GEOMETRIDAE	ENYPIA	VENATA	12
LEPIDOPTERA	GEOMETRIDAE	ERANNIS	TILIARIA	5 12
LEPIDOPTERA	GEOMETRIDAE	ERANNIS	VANCOUVERENSIS	12
LEPIDOPTERA	GEOMETRIDAE	EULYPE	HASTATA	9
LEPIDOPTERA	GEOMETRIDAE	EUPITHECIA	LONGIPALPATA	12
LEPIDOPTERA	GEOMETRIDAE	HIBERNIA	DEFOLIARIA	12
LEPIDOPTERA	GEOMETRIDAE	LAMBDINA	FISCELLARIA	12 16
LEPIDOPTERA	GEOMETRIDAE	LAMBDINA	FISCELLARIA LUGUBROSA	12 16
LEPIDOPTERA	GEOMETRIDAE	LAMBDINA	FISCELLARIA SOMNIARIA	12 16
LEPIDOPTERA	GEOMETRIDAE	MELANOLOPHIA	IMITATA	12
LEPIDOPTERA	GEOMETRIDAE	NEPYTIA	CANOSARIA	16
LEPIDOPTERA	GEOMETRIDAE	NEPYTIA	PHANTASMARIA	12
LEPIDOPTERA	GEOMETRIDAE	OPEROPHTERA	BRUCEATA	5 12
LEPIDOPTERA	GEOMETRIDAE	OPEROPHTERA	BRUMATA	5 12 16 17 19
LEPIDOPTERA	GEOMETRIDAE	OPEROPHTERA	FAGATA	5
LEPIDOPTERA	GEOMETRIDAE	OPISTHOGRAPTIS	LUTEOLATA	12
LEPIDOPTERA	GEOMETRIDAE	OPORINIA	AUTUMNATA	5 12
LEPIDOPTERA	GEOMETRIDAE	OURAPTERYX	SAMBUCARIA	5
LEPIDOPTERA	GEOMETRIDAE	PALEACRITA	VERNATA	5 12
LEPIDOPTERA	GEOMETRIDAE	PERIBATODES	SIMPLICIARIA	12
LEPIDOPTERA	GEOMETRIDAE	PERO	BEHRENSARIUS	12
LEPIDOPTERA	GEOMETRIDAE	PHIGALIA	PEDARIA	12

ORDER	FAMILY	GENUS	SPECIES	DISEASES
LEPIDOPTERA	GEOMETRIDAE	PHIGALIA	TITEA	12
LEPIDOPTERA	GEOMETRIDAE	PROTOBOARMIA	PORCELARIA INDICATARIA	12
LEPIDOPTERA	GEOMETRIDAE	PTYCHOPODA	SERTATA	12 16
LEPIDOPTERA	GEOMETRIDAE	SABULODES	CABERATA	9 16
LEPIDOPTERA	GEOMETRIDAE	SELENIA	LUNARIA	5
LEPIDOPTERA	GEOMETRIDAE	SELIDOSEMA	SUAVIS	12
LEPIDOPTERA	GEOMETRIDAE	SEMIOTHISA	LITURATA	5
LEPIDOPTERA	GEOMETRIDAE	SEMIOTHISA	SEXMACULATA	9
LEPIDOPTERA	GEOMETRIDAE	SYNAXIS	PALLULATA	12
LEPIDOPTERA	HEPIALIDAE	HEPIALUS	LUPULINUS	5
LEPIDOPTERA	HEPIALIDAE	METAHEPIALUS	XENOCTENIS	13
LEPIDOPTERA	HEPIALIDAE	ONCOPERA	ALBOGUTTATA	19
LEPIDOPTERA	HEPIALIDAE	WISEANA	CERVINATA	9 10 12 19
LEPIDOPTERA	HEPIALIDAE	WISEANA	UMBRACULATA	9 12 19
LEPIDOPTERA	HESPERIIDAE	EPARGYREUS	CLARUS	12
LEPIDOPTERA	HETEROGENEIDAE	PARASA	CONSOCIA	12
LEPIDOPTERA	LASIOCAMPIDAE	COSMOTRICHE	POTATORIA	12
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	PINI	12 16
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	SIBIRICUS	9
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	SPECTABILIS	5 12
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	SUPERANS	5
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	UNDANS	5 12
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	UNDANS FLAVEOLA	12
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	YAMADAI	5 12
LEPIDOPTERA	LASIOCAMPIDAE	ERIOGASTER	LANESTRIS	5
LEPIDOPTERA	LASIOCAMPIDAE	GASTROPACHA	QUERCIFOLIA	5
LEPIDOPTERA	LASIOCAMPIDAE	GASTROPACHA	QUERCIFOLIA CERRIDIFOLIA	5 12
LEPIDOPTERA	LASIOCAMPIDAE	GONOMETA	PODOCARPI	13
LEPIDOPTERA	LASIOCAMPIDAE	LASIOCAMPA	QUERCUS	5
LEPIDOPTERA	LASIOCAMPIDAE	LASIOCAMPA	TRIFOLII	12
LEPIDOPTERA	LASIOCAMPIDAE	MACROTHYLACIA	RUBI	12
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	ALPICOLA	12
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	AMERICANUM	5 12 16
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	CALIFORNICUM	12
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	CONSTRICTUM	12
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	DISSTRIA	5 12 16
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	FRAGILE	12
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	LUTESCENS	12
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	NEUSTRIA	5 12 16
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	NEUSTRIA TESTACEA	5 12 16
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	PLUVIALE	12
LEPIDOPTERA	LIMACODIDAE	NIPHADOLEPIS	ALIANTA	17
LEPIDOPTERA	LIMACODIDAE	DARNA	TRIMA	9 13
LEPIDOPTERA	LIMACODIDAE	NAROSA	CONSPERSA	17
LEPIDOPTERA	LIMACODIDAE	NATADA	NARARIA	9
LEPIDOPTERA	LIMACODIDAE	PARASA	LEPIDA	17
LEPIDOPTERA	LIMACODIDAE	SPATULIFIMBRIA	CASTANEICEPS	17
LEPIDOPTERA	LIMACODIDAE	THOSEA	CANA	17
LEPIDOPTERA	LIMACODIDAE	THOSEA	CERVINA	17
LEPIDOPTERA	LIMACODIDAE	THOSEA	RECTA	17
LEPIDOPTERA	LYCAENIDAE	LYCAENA	PHLAEAS	5
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	CONFUSA	12
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	MENDOSA	12
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	PLAGIATA	12
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	PSEUDABIETIS	12
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	PUDIBUNDA	5 12 16
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	SELENITICA	16
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	CHRYSORRHOEA	5 12 16
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	FLAVA	12
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	PSEUDOCONSPERSA	12
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	SIMILIS	5 12
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	SUBFLAVA	12
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	TERMINALIS	16
LEPIDOPTERA	LYMANTRIIDAE	IVELA	AURIPES	12
LEPIDOPTERA	LYMANTRIIDAE	LYMANTRIA	FUMIDA FUMIDA	5 12
LEPIDOPTERA	LYMANTRIIDAE	LYMANTRIA	INCERTA	12
LEPIDOPTERA	LYMANTRIIDAE	LYMANTRIA	MATHURA AURORA	5 12
LEPIDOPTERA	LYMANTRIIDAE	LYMANTRIA	MONACHA	5 12 16
LEPIDOPTERA	LYMANTRIIDAE	NYGMIA	PHAEORRHOEA	16
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	ANARTOIDES	12
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	ANTIQUA	5 12 16
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	AUSTRALIS	12
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	BADIA	12
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	GONOSTIGMA	12
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	LEUCOSTIGMA	5 12 16
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	PSEUDOTSUGATA	5 12 16
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	TURBATA	12
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	VETUSTA	12
LEPIDOPTERA	LYMANTRIIDAE	PORTHESIA	XANTHOCAMPA	5
LEPIDOPTERA	LYMANTRIIDAE	PORTHETRIA	DISPAR	5 6 10 12 16

ORDER	FAMILY	GENUS	SPECIES	DISEASES
LEPIDOPTERA	LYMANTRIIDAE	PORTHETRIA	DISPAR JAPONICA	5 12
LEPIDOPTERA	LYMANTRIIDAE	PORTHETRIA	OBFUSCATA	12
LEPIDOPTERA	LYMANTRIIDAE	STILPNOTIA	SALICIS	12 16
LEPIDOPTERA	LYONETIIDAE	BUCCULATRIX	THURBERIELLA	12
LEPIDOPTERA	MEGALOPHYGIDAE	MEGALOPYGE	OPERCULARIS	9
LEPIDOPTERA	NOCTUIDAE	ACHAEA	JANATA	9
LEPIDOPTERA	NOCTUIDAE	ACRONICTA	ACERIS	12
LEPIDOPTERA	NOCTUIDAE	ACTEBIA	FENNICA	12
LEPIDOPTERA	NOCTUIDAE	ADRIS	TYRANNUS AMURENSIS	5
LEPIDOPTERA	NOCTUIDAE	AEDIA	LEUCOMELAS	12
LEPIDOPTERA	NOCTUIDAE	AGROCHOLA	LYCHNIDIS	5
LEPIDOPTERA	NOCTUIDAE	AGROTIS	IPSILON	12
LEPIDOPTERA	NOCTUIDAE	AGROTIS	SEGETUM	5 9 12
LEPIDOPTERA	NOCTUIDAE	ALABAMA	ARGILLACEA	12 16
LEPIDOPTERA	NOCTUIDAE	ALETIA	OXYGALA LUTEOPALLENS	12
LEPIDOPTERA	NOCTUIDAE	AMATHES	C-NIGRUM	12
LEPIDOPTERA	NOCTUIDAE	AMATHES	GLAREOSA	5
LEPIDOPTERA	NOCTUIDAE	ANAGRAPHA	FALCIFERA	12
LEPIDOPTERA	NOCTUIDAE	ANCHOSCELI	HELVOLA	5
LEPIDOPTERA	NOCTUIDAE	ANOMIS	FLAVA	12
LEPIDOPTERA	NOCTUIDAE	ANOMOGYNA	ELIMATA	12
LEPIDOPTERA	NOCTUIDAE	ANTICARSIA	GEMMATILIS	16
LEPIDOPTERA	NOCTUIDAE	ANTITYPE	XANTHOMISTA	5
LEPIDOPTERA	NOCTUIDAE	ARCTE	COERULEA	5
LEPIDOPTERA	NOCTUIDAE	AUTOGRAPHA	BILOBA	12 16
LEPIDOPTERA	NOCTUIDAE	AUTOGRAPHA	CALIFORNICA	5 9 12
LEPIDOPTERA	NOCTUIDAE	AUTOGRAPHA	GAMMA	5 12
LEPIDOPTERA	NOCTUIDAE	AUTOGRAPHA	NIGRISIGNA	12
LEPIDOPTERA	NOCTUIDAE	AUTOGRAPHA	PRECATIONIS	12
LEPIDOPTERA	NOCTUIDAE	BELLURA	GORTYNOIDES	12
LEPIDOPTERA	NOCTUIDAE	CALOPHASIA	LUNULA	5 12
LEPIDOPTERA	NOCTUIDAE	CATABENA	ESULA	12 16
LEPIDOPTERA	NOCTUIDAE	CATOCALA	CONJUNCTA	12
LEPIDOPTERA	NOCTUIDAE	CATOCALA	NYMPHAEA	12
LEPIDOPTERA	NOCTUIDAE	CATOCALA	NYMPHAGOGA	12
LEPIDOPTERA	NOCTUIDAE	CERAMICA	PICTA	5 12
LEPIDOPTERA	NOCTUIDAE	CHRYSODEIXIS	CHALCITES	12
LEPIDOPTERA	NOCTUIDAE	DIATARAXIA	OLERACEA	5 9
LEPIDOPTERA	NOCTUIDAE	DICYCLA	OO	12
LEPIDOPTERA	NOCTUIDAE	DIPAROPSIS	WATERSI	12
LEPIDOPTERA	NOCTUIDAE	DRYOBOTA	FURVA	9 12
LEPIDOPTERA	NOCTUIDAE	DRYOBOTA	PROTEA	12
LEPIDOPTERA	NOCTUIDAE	DRYOBOTODES	MONOCHROMA	12
LEPIDOPTERA	NOCTUIDAE	EUPLEXIA	LUCIPARA	9
LEPIDOPTERA	NOCTUIDAE	EUPSILIS	SATELLITIA	9
LEPIDOPTERA	NOCTUIDAE	EUXOA	AUXILIARIS	9 12 13 16 19
LEPIDOPTERA	NOCTUIDAE	EUXOA	MESSORIA	5 12
LEPIDOPTERA	NOCTUIDAE	EUXOA	OCHROGASTER	5 9 12 16
LEPIDOPTERA	NOCTUIDAE	FELTIA	SUBTERRANEA	9
LEPIDOPTERA	NOCTUIDAE	HADA	NANA	5
LEPIDOPTERA	NOCTUIDAE	HADENA	BASILINEA	9
LEPIDOPTERA	NOCTUIDAE	HADENA	SERENA	5
LEPIDOPTERA	NOCTUIDAE	HADENA	SORDIDA	9 12
LEPIDOPTERA	NOCTUIDAE	HELIOPHOBUS	ALBICOLON	5
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	ARMIGERA	5 9 12
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	ASSULTA	12
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	OBSOLETA	12
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	OBTECTUS	12
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	PELTIGERA	12
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	PHLOXIPHAGA	12 16
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	PUNCTIGERA	9 12
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	RUBRESCENS	9
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	SUBFLEXA	12
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	VIRESCENS	5 12 16
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	ZEA	5 9 12 13
LEPIDOPTERA	NOCTUIDAE	LAMPRA	FIMBRIATA	5
LEPIDOPTERA	NOCTUIDAE	LITHOPHANE	LEAUTIERI	5
LEPIDOPTERA	NOCTUIDAE	MAMESTRA	BRASSICAE	5 6 12
LEPIDOPTERA	NOCTUIDAE	MAMESTRA	CONFIGURATA	12
LEPIDOPTERA	NOCTUIDAE	MANIA	MAURA	5
LEPIDOPTERA	NOCTUIDAE	MELANCHRA	PERSICARIAE	9
LEPIDOPTERA	NOCTUIDAE	MOCTS	UNDATA	5
LEPIDOPTERA	NOCTUIDAE	MOMA	CHAMPA	12
LEPIDOPTERA	NOCTUIDAE	NEPHELODES	EMMEDONIA	9 12 16
LEPIDOPTERA	NOCTUIDAE	OPHIUSA	CORONATA	17
LEPIDOPTERA	NOCTUIDAE	ORAESIA	EMARGINATA	5 12
LEPIDOPTERA	NOCTUIDAE	ORAESIA	EXCAVATA	5
LEPIDOPTERA	NOCTUIDAE	PANOLIS	FLAMMEA	12 16
LEPIDOPTERA	NOCTUIDAE	PANTHEA	PORTLANDIA	12
LEPIDOPTERA	NOCTUIDAE	PAPAIPEMA	PURPURIFASCIA	9

ORDER	FAMILY	GENUS	SPECIES	DISEASES
LEPIDOPTERA	NOCTUIDAE	PERIDROMA	SAUCIA	9 12 16
LEPIDOPTERA	NOCTUIDAE	PERSECTANIA	EWINGII	9
LEPIDOPTERA	NOCTUIDAE	PHLOGOPHORA	METICULOSA	5 12
LEPIDOPTERA	NOCTUIDAE	PLATHYPENA	SCABRA	9
LEPIDOPTERA	NOCTUIDAE	PLUSIA	ARGENTIFERA	12
LEPIDOPTERA	NOCTUIDAE	PLUSIA	ORICHALCEA	12
LEPIDOPTERA	NOCTUIDAE	PODIOPLUSIA	PEPONIS	12
LEPIDOPTERA	NOCTUIDAE	PRODENIA	ANDROGEA	9
LEPIDOPTERA	NOCTUIDAE	PRODENIA	LITOSIA	12
LEPIDOPTERA	NOCTUIDAE	PRODENIA	ORNITHOGALLI	12 16
LEPIDOPTERA	NOCTUIDAE	PRODENIA	PRAEFICA	12
LEPIDOPTERA	NOCTUIDAE	PRODENIA	TERRICOLA	12
LEPIDOPTERA	NOCTUIDAE	PSEUDALETIA	CONVECTA	9 12
LEPIDOPTERA	NOCTUIDAE	PSEUDALETIA	SEPARATA	9 12 13
LEPIDOPTERA	NOCTUIDAE	PSEUDALETIA	UNIPUNCTA	5 9 10 12 13 16
LEPIDOPTERA	NOCTUIDAE	PSEUDOPLUSIA	INCLUDENS	12
LEPIDOPTERA	NOCTUIDAE	RACHIPLUSIA	NU	12 16
LEPIDOPTERA	NOCTUIDAE	RACHIPLUSIA	OU	12
LEPIDOPTERA	NOCTUIDAE	SCOLIOPTERYX	LIBATRIX	5 12
LEPIDOPTERA	NOCTUIDAE	SESAMIA	CRETICA	9
LEPIDOPTERA	NOCTUIDAE	SESAMIA	NONAGRIOIDES	9
LEPIDOPTERA	NOCTUIDAE	SPAELOTIS	CLANDESTINA	16
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	EXEMPTA	12 17
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	EXIGUA	5 9 12
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	FRUGIPERDA	9 12 16
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	LITTORALIS	5 9 12 16
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	MAURITIA	12 16
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	MAURITIA ACRONYCTOIDES	12
LEPIDOPTERA	NOCTUIDAE	SYNOGRAPHA	SELECTA	12
LEPIDOPTERA	NOCTUIDAE	TRICHOPLUSIA	NI	5 9 10 12
LEPIDOPTERA	NOCTUIDAE	TRIPHAENA	PRONUBA	5
LEPIDOPTERA	NOCTUIDAE	XYLOMYGES	CONSPICILLARIS	5
LEPIDOPTERA	NOTODONTIDAE	CERURA	HERMELINA	12 16
LEPIDOPTERA	NOTODONTIDAE	CERURA	VINULA	5
LEPIDOPTERA	NOTODONTIDAE	HETEROCAMPA	GUTTIVITA	16
LEPIDOPTERA	NOTODONTIDAE	LOPHOPTERYX	CAPUCINA	5
LEPIDOPTERA	NOTODONTIDAE	NADATA	GIBBOSA	12
LEPIDOPTERA	NOTODONTIDAE	PHALERA	BUCEPHALA	5 12
LEPIDOPTERA	NOTODONTIDAE	PYGAERA	ANASTOMOSIS	5 9 12 17
LEPIDOPTERA	NOTODONTIDAE	PYGAERA	ANASTOMOSIS ORIENTALIS	5 12
LEPIDOPTERA	NOTODONTIDAE	PYGAERA	ANASTOMOSIS TRISTIS	5 12
LEPIDOPTERA	NOTODONTIDAE	SCHIZURA	CONCINNA	5
LEPIDOPTERA	NOTODONTIDAE	STAUROPUS	ALTERNUS	16
LEPIDOPTERA	NYMPHALIDAE	AGLAIS	URTICAE	5 9 12 16
LEPIDOPTERA	NYMPHALIDAE	AGRAULIS	VANILLAE	12
LEPIDOPTERA	NYMPHALIDAE	ARGYNNIS	DIA	5
LEPIDOPTERA	NYMPHALIDAE	ARGYNNIS	LATHONIA	16
LEPIDOPTERA	NYMPHALIDAE	ARGYNNIS	PAPHIA	12 16
LEPIDOPTERA	NYMPHALIDAE	ASTEROCAMPA	CELTIS	12
LEPIDOPTERA	NYMPHALIDAE	CHARAXES	JASIUS	16
LEPIDOPTERA	NYMPHALIDAE	JUNONIA	COENIA	6 9 12 16
LEPIDOPTERA	NYMPHALIDAE	NYMPHALIS	ANTIOPA	5 9 12 16
LEPIDOPTERA	NYMPHALIDAE	NYMPHALIS	IO	5 12 16
LEPIDOPTERA	NYMPHALIDAE	NYMPHALIS	POLYCHLOROS	16
LEPIDOPTERA	NYMPHALIDAE	POLYGONIA	C-ALBUM	5 12
LEPIDOPTERA	NYMPHALIDAE	POLYGONIA	SATYRUS	12
LEPIDOPTERA	NYMPHALIDAE	VANESSA	ATALANTA	12 16
LEPIDOPTERA	NYMPHALIDAE	VANESSA	CARDUI	5 12 16
LEPIDOPTERA	NYMPHALIDAE	VANESSA	TAMMEAMEA	16
LEPIDOPTERA	OECOPHORIDAE	DIURNEA	FAGELLA	16
LEPIDOPTERA	OLETHREUTIDAE	ARGYROPLOCE	LEUCOTRETA	5
LEPIDOPTERA	OLETHREUTIDAE	EXARTEMA	APPENDICEUM	9
LEPIDOPTERA	OLETHREUTIDAE	LASPEYRESIA	POMONELLA	9 16
LEPIDOPTERA	OLETHREUTIDAE	RHYACIONIA	DUPLANA	9 12
LEPIDOPTERA	OLETHREUTIDAE	SPILONOTA	OCELLANA	12
LEPIDOPTERA	OLETHREUTIDAE	ZEIRAPHERA	DINIANA	9 12 16 19
LEPIDOPTERA	PAMPHILIIDAE	CEPHALCIA	FASCIPENNIS	9
LEPIDOPTERA	PAPILIONIDAE	LUEHDORFIA	JAPONICA	12
LEPIDOPTERA	PAPILIONIDAE	PAPILIO	MACHAON	5
LEPIDOPTERA	PAPILIONIDAE	PAPILIO	PODALIRIUS	12
LEPIDOPTERA	PHALONIIDAE	CLYSIANA	AMBIGUELLA	16
LEPIDOPTERA	PHYCITIDAE	ANAGASTA	KUHNIELLA	12
LEPIDOPTERA	PHYCITIDAE	CACTOBLASTIS	CACTORUM	5
LEPIDOPTERA	PIERIDAE	APORIA	CRATAEGI	5 12 16
LEPIDOPTERA	PIERIDAE	COLIAS	CHRYSOTHEME CHRYSOTHEME	16
LEPIDOPTERA	PIERIDAE	COLIAS	ELECTO	12 16
LEPIDOPTERA	PIERIDAE	COLIAS	EURYTHEME	5 12
LEPIDOPTERA	PIERIDAE	COLIAS	LESBIA	12
LEPIDOPTERA	PIERIDAE	COLIAS	PHILODICE	12 16
LEPIDOPTERA	PIERIDAE	EUCHLOE	CARDAMINES	5

ORDER	FAMILY	GENUS	SPECIES	DISEASES			
LEPIDOPTERA	PIERIDAE	GONEPTERYX	RHAMNI	5			
LEPIDOPTERA	PIERIDAE	PIERIS	BRASSICAE	5	9	10	
LEPIDOPTERA	PIERIDAE	PIERIS	BRASSICAE CHEIRANTHI	9			
LEPIDOPTERA	PIERIDAE	PIERIS	NAPI	9			
LEPIDOPTERA	PIERIDAE	PIERIS	RAPAE	5	9	12	16
LEPIDOPTERA	PIERIDAE	PIERIS	RAPAE CRUCIVORA	5	9	12	
LEPIDOPTERA	PSYCHIDAE	CANEPHORA	ASIATICA	12			
LEPIDOPTERA	PSYCHIDAE	CRYPTOTHELEA	JUNODI	12			
LEPIDOPTERA	PSYCHIDAE	MAHASENA	MINUSCULA	12			
LEPIDOPTERA	PSYCHIDAE	OIKETICUS	KIRBYI	5			
LEPIDOPTERA	PSYCHIDAE	ORIOPSYCHE	ANGUSTELLA	19			
LEPIDOPTERA	PSYCHIDAE	THYRIDOPTERYX	EPHEMERAEFORMIS	17			
LEPIDOPTERA	PYRALIDAE	ACROBASIS	ZELLERI	19			
LEPIDOPTERA	PYRALIDAE	CADRA	CAUTELLA	5	9	12	
LEPIDOPTERA	PYRALIDAE	CADRA	FIGULILELLA	9			
LEPIDOPTERA	PYRALIDAE	CHILO	SUPPRESSALIS	9	10	12	
LEPIDOPTERA	PYRALIDAE	CNAPHALOCROCIS	MEDINALIS	9			
LEPIDOPTERA	PYRALIDAE	CRYPTOBLABES	LARICIANA	12			
LEPIDOPTERA	PYRALIDAE	DICHOCROCIS	PUNCTIFERALIS	12			
LEPIDOPTERA	PYRALIDAE	DIORYCTRIA	ABIETELLA	9			
LEPIDOPTERA	PYRALIDAE	DIORYCTRIA	SPLENDIDELLA	17			
LEPIDOPTERA	PYRALIDAE	EPHESTIA	ELUTELLA	9	12		
LEPIDOPTERA	PYRALIDAE	NACOLEIA	DIEMENALIS	9			
LEPIDOPTERA	PYRALIDAE	NACOLEIA	OCTOSEMA	12			
LEPIDOPTERA	PYRALIDAE	OSTRINIA	NUBILALIS	17			
LEPIDOPTERA	PYRALIDAE	PARAMYELOIS	TRANSITELLA	12			
LEPIDOPTERA	PYRALIDAE	PLODIA	INTERPUNCTELLA	9	12		
LEPIDOPTERA	PYRALIDAE	NITILESIA	SABULOSELLA	10			
LEPIDOPTERA	PYRAUSTIDAE	BLEPHAROMASTIX	ACUTANGULALIS	16			
LEPIDOPTERA	PYRAUSTIDAE	OMIODES	BLACKBURNI	17			
LEPIDOPTERA	SATURNIIDAE	ACTIAS	LUNA	5			
LEPIDOPTERA	SATURNIIDAE	ACTIAS	SELENE	5	13		
LEPIDOPTERA	SATURNIIDAE	ANISOTA	SENATORIA	16			
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	EUCALYPTI	5	10	13	17
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	HELENA	13			
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	PAPHIA MYLITTA	5	12		
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	PERNYI	5	12	13	16
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	POLYPHEMUS	5	12	16	
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	YAMAMAI	12	16		
LEPIDOPTERA	SATURNIIDAE	AUTOMERIS	AURANTIACA	5			
LEPIDOPTERA	SATURNIIDAE	AUTOMERIS	MEMUSAE	5			
LEPIDOPTERA	SATURNIIDAE	COLORADIA	PANDORA	12	16		
LEPIDOPTERA	SATURNIIDAE	DICTYOPLOCA	JAPONICA	5	12		
LEPIDOPTERA	SATURNIIDAE	HEMILEUCA	MAIA	16			
LEPIDOPTERA	SATURNIIDAE	HEMILEUCA	OLIVIAE	16			
LEPIDOPTERA	SATURNIIDAE	HEMILEUCA	TRICOLOR	12	16		
LEPIDOPTERA	SATURNIIDAE	HYALOPHORA	CECROPIA	5	12	13	
LEPIDOPTERA	SATURNIIDAE	HYLESIA	NIGRICANS	12			
LEPIDOPTERA	SATURNIIDAE	NUDAURELIA	CYTHEREA CLARKI	13			
LEPIDOPTERA	SATURNIIDAE	NUDAURELIA	CYTHEREA CYTHEREA	13	16		
LEPIDOPTERA	SATURNIIDAE	PSEUDOBUNAEA	IRIUS	17			
LEPIDOPTERA	SATURNIIDAE	PSEUDOHAZIS	EGLANTERINA	16			
LEPIDOPTERA	SATURNIIDAE	SAMIA	CYNTHIA	5	12	13	16
LEPIDOPTERA	SATURNIIDAE	SAMIA	PRYERI	5	12		
LEPIDOPTERA	SATURNIIDAE	SAMIA	RICINI	5	12	13	16
LEPIDOPTERA	SATURNIIDAE	SATURNIA	PYRI	5	12	16	
LEPIDOPTERA	SATYRIDAE	DIRA	MEGERA	5			
LEPIDOPTERA	SATYRIDAE	PARARGE	AEGERIA	5			
LEPIDOPTERA	SPHINGIDAE	CELERIO	EUPHORBIAE	5	12	16	
LEPIDOPTERA	SPHINGIDAE	CELERIO	GALII	12	16		
LEPIDOPTERA	SPHINGIDAE	CELERIO	HARMUTHI	16			
LEPIDOPTERA	SPHINGIDAE	CELERIO	KINDERVATERI	16			
LEPIDOPTERA	SPHINGIDAE	CELERIO	PHILEUPHORBIAE	16			
LEPIDOPTERA	SPHINGIDAE	CELERIO	VESPERTILIO	16			
LEPIDOPTERA	SPHINGIDAE	DEILEPHILA	ELPENOR	5	12	16	
LEPIDOPTERA	SPHINGIDAE	DILINA	TILIAE	5			
LEPIDOPTERA	SPHINGIDAE	HERSE	CONVOLVULI	5			
LEPIDOPTERA	SPHINGIDAE	LAOTHOE	POPULI	5	12		
LEPIDOPTERA	SPHINGIDAE	MANDUCA	QUINQUEMACULATA	9			
LEPIDOPTERA	SPHINGIDAE	MANDUCA	SEXTA	9	12		
LEPIDOPTERA	SPHINGIDAE	PACHYSPHINX	MODESTA	5			
LEPIDOPTERA	SPHINGIDAE	PROSERPINUS	PROSERPINA	16			
LEPIDOPTERA	SPHINGIDAE	PSILOGRAMMA	MENEPHRON	9			
LEPIDOPTERA	SPHINGIDAE	SMERINTHUS	OCELLATA	5	12	16	
LEPIDOPTERA	SPHINGIDAE	SMERINTHUS	OCELLATA ATLANTICUS	12	16		
LEPIDOPTERA	SPHINGIDAE	SPHINX	LIGUSTRI	5	12		
LEPIDOPTERA	SPHINGIDAE	SPHINX	PINASTRI	5	12		
LEPIDOPTERA	SPHINGIDAE	THERETRA	JAPONICA	12			
LEPIDOPTERA	TENTHREDINIDAE	PIKONEMA	DIMMOCKII	12			
LEPIDOPTERA	THAUMETOPOEIDAE	THAUMETOPOEA	PITYOCAMPA	5	9	12	

ORDER	FAMILY	GENUS	SPECIES	DISEASES
LEPIDOPTERA	THAUMETOPOEIDAE	THAUMETOPOEA	PROCESSIONEA	5 12
LEPIDOPTERA	THAUMETOPOEIDAE	THAUMETOPOEA	WILKINSONI	5 12
LEPIDOPTERA	TINEIDAE	TINEA	COLUMBARIELLA	16
LEPIDOPTERA	TINEIDAE	TINEA	PELLIONELLA	5 12
LEPIDOPTERA	TINEIDAE	TINEOLA	BISSELLIELLA	5 12 16
LEPIDOPTERA	TORTRICIDAE	ACLERIS	GLOVERANA	12
LEPIDOPTERA	TORTRICIDAE	ACLERIS	VARIANA	12
LEPIDOPTERA	TORTRICIDAE	ADOXOPHYES	FASCIATA	5 9
LEPIDOPTERA	TORTRICIDAE	ADOXOPHYES	ORANA	9
LEPIDOPTERA	TORTRICIDAE	ADOXOPHYES	RETICULANA	5 12
LEPIDOPTERA	TORTRICIDAE	AMELIA	PALLORANA	9
LEPIDOPTERA	TORTRICIDAE	ARCHIPPUS	ISSHIKII	19
LEPIDOPTERA	TORTRICIDAE	ARCHIPS	ARGYROSPILUS	9
LEPIDOPTERA	TORTRICIDAE	ARCHIPS	CERASIVORANUS	12
LEPIDOPTERA	TORTRICIDAE	ARCHIPS	LONGICELLANA	9
LEPIDOPTERA	TORTRICIDAE	ARGYROTAENIA	VELUTINANA	9
LEPIDOPTERA	TORTRICIDAE	CACOECIA	MURINANA	9 12 16
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	BIENNIS	19
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	CONFLICTANA	19
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	DIVERSANA	19
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	FUMIFERANA	5 9 12 19
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	OCCIDENTALIS	12
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	PINUS	12
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	ROSACEANA	12
LEPIDOPTERA	TORTRICIDAE	EPIPHYAS	POSTVITTANA	12
LEPIDOPTERA	TORTRICIDAE	HOMONA	COFFEARIA	16
LEPIDOPTERA	TORTRICIDAE	HOMONA	MAGNANIMA	5 12
LEPIDOPTERA	TORTRICIDAE	LATHRONYMPHA	PHASEOLI	9
LEPIDOPTERA	TORTRICIDAE	MEROPHYAS	DIVULSANA	12
LEPIDOPTERA	TORTRICIDAE	PANDEMIS	LAMPROSANA	12
LEPIDOPTERA	TORTRICIDAE	PTYCHOLOMOIDES	AERIFERANA	12
LEPIDOPTERA	TORTRICIDAE	SPARGANOTHIS	PETTITANA	12
LEPIDOPTERA	TORTRICIDAE	TORTRIX	LOEFLINGIANA	12 16
LEPIDOPTERA	TORTRICIDAE	TORTRIX	VIRIDANA	5 12 16
LEPIDOPTERA	YPONOMEUTIDAE	ARGYRESTHIA	CUPRESSELLA	9
LEPIDOPTERA	YPONOMEUTIDAE	PLUTELLA	XYLOSTELLA	9 12
LEPIDOPTERA	YPONOMEUTIDAE	PRAYS	OLEELLUS	16
LEPIDOPTERA	ZYGAENIDAE	AGLAOPE	INFAUSTA	5
LEPIDOPTERA	ZYGAENIDAE	HARRISINA	BRILLIANS	9
NEUROPTERA	CHRYSOPIDAE	CHRYSOPA	PERLA	5 12
NEUROPTERA	HEMEROBIIDAE	HEMEROBIUS	STIGMA	5 12
NEUROPTERA	MYRMELEONTIDAE	HAGENOMYIA	MICANS	16
ORTHOPTERA	ACRIDIDAE	AMPHITORNUS	COLORADUS	4
ORTHOPTERA	ACRIDIDAE	AULOCARA	ELLIOTTI	4
ORTHOPTERA	ACRIDIDAE	LOCUSTA	MIGRATORIA	17
ORTHOPTERA	ACRIDIDAE	MELANOPLUS	BIVITTATUS	4 12
ORTHOPTERA	ACRIDIDAE	MELANOPLUS	DAWSONI	4
ORTHOPTERA	ACRIDIDAE	MELANOPLUS	DIFFERENTIALIS	4 12
ORTHOPTERA	ACRIDIDAE	MELANOPLUS	FEMURRUBRUM	4
ORTHOPTERA	ACRIDIDAE	MELANOPLUS	SANGUINIPES	4 12 19
ORTHOPTERA	ACRIDIDAE	SCHISTOCERCA	AMERICANA	4 12
ORTHOPTERA	ACRIDIDAE	SCHISTOCERCA	VAGA	4
ORTHOPTERA	GRYLLIDAE	ACHETA	DOMESTICUS	17
ORTHOPTERA	GRYLLIDAE	GRYLLUS	BIMACULATUS	15
ORTHOPTERA	GRYLLIDAE	TELEOGRYLLUS	COMMODUS	13
ORTHOPTERA	GRYLLIDAE	TELEOGRYLLUS	OCEANICUS	13
TRICHOPTERA	LIMNEPHILIDAE	NEOPHYLAX	SP.	12

APPENDIX 2

Alphabetical List of Hosts by Specific Names

ORDER	FAMILY	GENUS	SPECIES	DISEASES
LEPIDOPTERA	PYRALIDAE	DIORYCTRIA	ABIETELLA	9
HYMENOPTERA	PAMPHILIIDAE	CEPHALCIA	ABIETIS	16
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	ABIETIS	12 16
LEPIDOPTERA	NOCTUIDAE	ACRONICTA	ACERIS	12
LEPIDOPTERA	ARCTIIDAE	ESTIGMENE	ACREA	5 9 12 16 19
LEPIDOPTERA	PYRAUSTIDAE	BLEPHAROMASTIX	ACUTANGULALIS	16
ISOPTERA	TERMOPSIDAE	POROTERMES	ADAMSONI	17
LEPIDOPTERA	SATYRIDAE	PARARGE	AEGERIA	5
DIPTERA	CULICIDAE	AEDES	AEGYPTI	5 10 12 17
LEPIDOPTERA	TORTRICIDAE	PTYCHOLOMOIDES	AERIFERANA	12
DIPTERA	DROSOPHILIDAE	DROSOPHILA	AFFINIS	3
HYMENOPTERA	BOMBIDAE	BOMBUS	AGRORUM	1
LEPIDOPTERA	NOCTUIDAE	HELIOPHOBUS	ALBICOLON	5
DIPTERA	CULICIDAE	ANOPHELES	ALBIMANUS	10 19
LEPIDOPTERA	ARCTIIDAE	AMSACTA	ALBISTRIGA	12
LEPIDOPTERA	HEPIALIDAE	ONCOPERA	ALBOGUTTATA	19
COLEOPTERA	SCARABAEIDAE	DERMOLEPIDA	ALBOHIRTUM	19
LEPIDOPTERA	LIMACODIDAE	NIPHADOLEPIS	ALIANTA	17
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	ALPICOLA	12
HYMENOPTERA	PAMPHILIIDAE	CEPHALCIA	ALPINA	16
LEPIDOPTERA	NOTODONTIDAE	STAUROPUS	ALTERNUS	16
LEPIDOPTERA	ARCTIIDAE	DIONYCHOPUS	AMASIS	9 13
LEPIDOPTERA	PHALONIIDAE	CLYSIANA	AMBIGUELLA	16
ORTHOPTERA	ACRIDIDAE	SCHISTOCERCA	AMERICANA	4 12
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	AMERICANUM	5 12 16
LEPIDOPTERA	ANTHELIDAE	PTEROLOCERA	AMPLICORNIS	12
DIPTERA	DROSOPHILIDAE	DROSOPHILA	ANANASSAE	13
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	ANARTOIDES	12
LEPIDOPTERA	NOTODONTIDAE	PYGAERA	ANASTOMOSIS	5 9 12 17
LEPIDOPTERA	NOTODONTIDAE	PYGAERA	ANASTOMOSIS ORIENTALIS	5 12
LEPIDOPTERA	NOTODONTIDAE	PYGAERA	ANASTOMOSIS TRISTIS	5 12
LEPIDOPTERA	NOCTUIDAE	PRODENIA	ANDROGEA	9
DIPTERA	SCIARIDAE	RHYNCHOSCIARA	ANGELAE	12 17
LEPIDOPTERA	PSYCHIDAE	OPIOPSYCHE	ANGUSTELLA	19
DIPTERA	CULICIDAE	AEDES	ANNULIPES	10
LEPIDOPTERA	NYMPHALIDAE	NYMPHALIS	ANTIOPA	5 9 12 16
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	ANTIQUA	5 12 16
LEPIDOPTERA	OLETHREUTIDAE	EXARTEMA	APPENDICEUM	9
DIPTERA	CHAOBORIDAE	CORETHRELLA	APPENDICULATA	10
COLEOPTERA	SCARABAEIDAE	HETERONYCHUS	ARATOR	13
LEPIDOPTERA	ARCTIIDAE	HALISIDOTA	ARGENTATA	12
LEPIDOPTERA	NOCTUIDAE	PLUSIA	ARGENTIFERA	12
LEPIDOPTERA	NOCTUIDAE	ALABAMA	ARGILLACEA	12 16
LEPIDOPTERA	TORTRICIDAE	ARCHIPS	ARGYROSPILUS	9
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	ARMIGERA	5 9 12
LEPIDOPTERA	PSYCHIDAE	CANEPHORA	ASIATICA	12
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	ASSULTA	12
LEPIDOPTERA	NYMPHALIDAE	VANESSA	ATALANTA	12 16
DIPTERA	CHIRONOMIDAE	CHIRONOMUS	ATTENUATUS	19
LEPIDOPTERA	SATURNIIDAE	AUTOMERIS	AURANTIACA	5
LEPIDOPTERA	LYMANTRIIDAE	IVELA	AURIPES	12
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	AUSTRALIS	12
COLEOPTERA	SCARABAEIDAE	SCAPANES	AUSTRALIS GROSSEPUNCTATUS	11
LEPIDOPTERA	GEOMETRIDAE	OPORINIA	AUTUMNATA	5 12
LEPIDOPTERA	NOCTUIDAE	EUXOA	AUXILIARIS	9 12 13 16 19
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	BADIA	12
LEPIDOPTERA	NOCTUIDAE	HADENA	BASILINEA	9
COLEOPTERA	SCARABAEIDAE	OTHNONIUS	BATESI	19
LEPIDOPTERA	GEOMETRIDAE	PERO	BEHRENSARIUS	12
LEPIDOPTERA	GEOMETRIDAE	BISTON	BETULARIA	5
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	BIENNIS	19
DIPTERA	DROSOPHILIDAE	DROSOPHILA	BIFASCIATA	17
LEPIDOPTERA	NOCTUIDAE	AUTOGRAPHA	BILOBA	12 16
ORTHOPTERA	GRYLLIDAE	GRYLLUS	BIMACULATUS	15
LEPIDOPTERA	TINEIDAE	TINEOLA	BISSELLIELLA	5 12 16
ORTHOPTERA	ACRIDIDAE	MELANOPLUS	BIVITTATUS	4 12
LEPIDOPTERA	PYRAUSTIDAE	OMIODES	BLACKBURNI	17
COLEOPTERA	SCARABAEIDAE	ORYCTES	BOAS	20
COLEOPTERA	SCARABAEIDAE	DEMODENA	BORANENSIS	19
DIPTERA	CHAOBORIDAE	CORETHRELLA	BRAKELEYI	10
LEPIDOPTERA	NOCTUIDAE	MAMESTRA	BRASSICAE	5 6 12
LEPIDOPTERA	PIERIDAE	PIERIS	BRASSICAE	5 9 10
LEPIDOPTERA	PIERIDAE	PIERIS	BRASSICAE CHEIRANTHI	9
LEPIDOPTERA	ZYGAENIDAE	HARRISINA	BRILLIANS	9
LEPIDOPTERA	GEOMETRIDAE	OPEROPHTERA	BRUCEATA	5 12
LEPIDOPTERA	GEOMETRIDAE	OPEROPHTERA	BRUMATA	5 12 16 17 19
LEPIDOPTERA	NOTODONTIDAE	PHALERA	BUCEPHALA	5 12
LEPIDOPTERA	NYMPHALIDAE	POLYGONIA	C-ALBUM	5 12
LEPIDOPTERA	NOCTUIDAE	AMATHES	C-NIGRUM	12
LEPIDOPTERA	GEOMETRIDAE	SABULODES	CABERATA	9 16

ORDER	FAMILY	GENUS	SPECIES	DISEASES				
LEPIDOPTERA	PHYCITIDAE	CACTOBLASTIS	CACTORUM	5				
LEPIDOPTERA	ARCTIIDAE	ARCTIA	CAJA	5	12	16		
LEPIDOPTERA	NOCTUIDAE	AUTOGRAPHA	CALIFORNICA	5	9	12		
LEPIDOPTERA	DIOPTIDAE	PHRYGANIDIA	CALIFORNICA	12				
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	CALIFORNICUM	12				
LEPIDOPTERA	LIMACODIDAE	THOSEA	CANA	17				
LEPIDOPTERA	GEOMETRIDAE	NEPYTIA	CANOSARIA	16				
DIPTERA	CULICIDAE	AEDES	CANTANS	10				
DIPTERA	TEPHRITIDAE	CERATITIS	CAPITATA	3				
LEPIDOPTERA	NOTODONTIDAE	LOPHOPTERYX	CAPUCINA	5				
LEPIDOPTERA	PIERIDAE	EUCHLOE	CARDAMINES	5				
LEPIDOPTERA	NYMPHALIDAE	VANESSA	CARDUI	5	12	16		
LEPIDOPTERA	ARCTIIDAE	HALISIDOTA	CARYAE	12				
LEPIDOPTERA	LIMACODIDAE	SPATULIFIMBRIA	CASTANEICEPS	17				
LEPIDOPTERA	PYRALIDAE	CADRA	CAUTELLA	5	9	12		
LEPIDOPTERA	SATURNIIDAE	HYALOPHORA	CECROPIA	5	12	13		
LEPIDOPTERA	NYMPHALIDAE	ASTEROCAMPA	CELTIS	12				
LEPIDOPTERA	GALLERIIDAE	CORCYRA	CEPHALONICA	12				
LEPIDOPTERA	TORTRICIDAE	ARCHIPS	CERASIVORANUS	12				
LEPIDOPTERA	LIMACODIDAE	THOSEA	CERVINA	17				
LEPIDOPTERA	HEPIALIDAE	WISEANA	CERVINATA	9	10	12	19	
LEPIDOPTERA	NOCTUIDAE	CHRYSODEIXIS	CHALCITES	12				
LEPIDOPTERA	NOCTUIDAE	MOMA	CHAMPA	12				
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	CHRYSORRHOEA	5	12	16		
LEPIDOPTERA	PIERIDAE	COLIAS	CHRYSOTHEME CHRYSOTHEME	16				
HEMIPTERA	CICADELLIDAE	NEPHOTETTIX	CINCTICEPS	10				
ACARINA	TETRANYCHIDAE	TETRANYCHUS	CINNABARINUS	13	17			
ACARINA	TETRANYCHIDAE	PANONYCHUS	CITRI	13	17			
LEPIDOPTERA	NOCTUIDAE	SPAELOTIS	CLANDESTINA	16				
LEPIDOPTERA	HESPERIIDAE	EPARGYREUS	CLARUS	12				
LEPIDOPTERA	NYMPHALIDAE	JUNONIA	COENIA	6	9	12	16	
LEPIDOPTERA	NOCTUIDAE	ARCTE	COERULEA	5				
LEPIDOPTERA	TORTRICIDAE	HOMONA	COFFEARIA	16				
ORTHOPTERA	ACRIDIDAE	AMPHITORNUS	COLORADUS	4				
LEPIDOPTERA	TINEIDAE	TINEA	COLUMBARIELLA	16				
ORTHOPTERA	GRYLLIDAE	TELEOGRYLLUS	COMMODUS	13				
LEPIDOPTERA	NOTODONTIDAE	SCHIZURA	CONCINNA	5				
LEPIDOPTERA	NOCTUIDAE	MAMESTRA	CONFIGURATA	12				
DIPTERA	CULICIDAE	PSOROPHORA	CONFINNIS	10	12	17		
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	CONFLICTANA	19				
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	CONFUSA	12				
LEPIDOPTERA	NOCTUIDAE	CATOCALA	CONJUNCTA	12				
LEPIDOPTERA	HETEROGENEIDAE	PARASA	CONSOCIA	12				
LEPIDOPTERA	LIMACODIDAE	NAROSA	CONSPERSA	17				
LEPIDOPTERA	NOCTUIDAE	XYLOMYGES	CONSPICILLARIS	5				
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	CONSTRICTUM	12				
LEPIDOPTERA	AEGERIIDAE	BEMBECIA	CONTRACTA	5	12			
LEPIDOPTERA	NOCTUIDAE	PSEUDALETIA	CONVECTA	9	12			
LEPIDOPTERA	SPHINGIDAE	HERSE	CONVOLVULI	5				
LEPIDOPTERA	NOCTUIDAE	OPHIUSA	CORONATA	17				
LEPIDOPTERA	PIERIDAE	APORIA	CRATAEGI	5	12	16		
LEPIDOPTERA	GEOMETRIDAE	ECTROPIS	CREPUSCULARIA	16				
LEPIDOPTERA	NOCTUIDAE	SESAMIA	CRETICA	9				
DIPTERA	CULICIDAE	ANOPHELES	CRUCIANS	12				
LEPIDOPTERA	ARCTIIDAE	HYPHANTRIA	CUNEA	5	9	12	16	
LEPIDOPTERA	YPONOMEUTIDAE	ARGYRESTHIA	CUPRESSELLA	9				
LEPIDOPTERA	SATURNIIDAE	SAMIA	CYNTHIA	5	12	13	16	
LEPIDOPTERA	SATURNIIDAE	NUDAURELIA	CYTHEREA CLARKI	13				
LEPIDOPTERA	SATURNIIDAE	NUDAURELIA	CYTHEREA CYTHEREA	13	16			
ORTHOPTERA	ACRIDIDAE	MELANOPLUS	DAWSONI	4				
LEPIDOPTERA	GEOMETRIDAE	HIBERNIA	DEFOLIARIA	12				
HYMENOPTERA	TENTHREDINIDAE	ANOPLONYX	DESTRUCTOR	5				
DIPTERA	CULICIDAE	AEDES	DETRITUS	10				
LEPIDOPTERA	NYMPHALIDAE	ARGYNNIS	DIA	5				
LEPIDOPTERA	PYRALIDAE	NACOLEIA	DIEMENALIS	9				
ORTHOPTERA	ACRIDIDAE	MELANOPLUS	DIFFERENTIALIS	4	12			
LEPIDOPTERA	TENTHREDINIDAE	PIKONEMA	DIMMOCKII	12				
LEPIDOPTERA	OLETHREUTIDAE	ZEIRAPHERA	DINIANA	9	12	16	19	
LEPIDOPTERA	LYMANTRIIDAE	PORTHETRIA	DISPAR	5	5	10	12	16
LEPIDOPTERA	LYMANTRIIDAE	PORTHETRIA	DISPAR JAPONICA	5	12			
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	DISSTRIA	5	12	16		
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	DIVERSANA	19				
LEPIDOPTERA	GEOMETRIDAE	CARIPETA	DIVISATA	12				
LEPIDOPTERA	TORTRICIDAE	MEROPHYAS	DIVULSANA	12				
DIPTERA	MUSCIDAE	MUSCA	DOMESTICA	3				
ORTHOPTERA	GRYLLIDAE	ACHETA	DOMESTICUS	17				
LEPIDOPTERA	ARCTIIDAE	PANAXIA	DOMINULA	5	12			
DIPTERA	CULICIDAE	AEDES	DORSALIS	10				
LEPIDOPTERA	OLETHREUTIDAE	RHYACIONIA	DUPLANA	9	12			
LEPIDOPTERA	SATURNIIDAE	PSEUDOHAZIS	EGLANTERINA	16				

ORDER	FAMILY	GENUS	SPECIES	DISEASES
LEPIDOPTERA	PIERIDAE	COLIAS	ELECTO	12 16
LEPIDOPTERA	NOCTUIDAE	ANOMOGYNA	ELIMATA	12
LEPIDOPTERA	GEOMETRIDAE	CROCALLIS	ELINGUARIA	5
ORTHOPTERA	ACRIDIDAE	AULOCARA	ELLIOTTI	4
LEPIDOPTERA	SPHINGIDAE	DEILEPHILA	ELPENOR	5 12 16
LEPIDOPTERA	PYRALIDAE	EPHESTIA	ELUTELLA	9 12
LEPIDOPTERA	NOCTUIDAE	ORAESIA	EMARGINATA	5 12
LEPIDOPTERA	NOCTUIDAE	NEPHELODES	EMMEDONIA	9 12 16
LEPIDOPTERA	PSYCHIDAE	THYRIDOPTERYX	EPHEMERAEFORMIS	17
HYMENOPTERA	TENTHREDINIDAE	PRISTIPHORA	ERICHSONII	12 16
LEPIDOPTERA	NOCTUIDAE	CATABENA	ESULA	12 15
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	EUCALYPTI	5 13 13 17
LEPIDOPTERA	SPHINGIDAE	CELERIO	EUPHORBIAE	5 12 16
LEPIDOPTERA	PIERIDAE	COLIAS	EURYTHEME	5 12
LEPIDOPTERA	NOCTUIDAE	PERSECTANIA	EWINGII	9
LEPIDOPTERA	NOCTUIDAE	ORAESIA	EXCAVATA	5
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	EXEMPTA	12 17
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	EXIGUA	5 9 12
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	EXITANS	12
ISOPTERA	TERMITIDAE	NASUTITERMES	EXITIOSUS	17
LEPIDOPTERA	GEOMETRIDAE	OPEROPHTERA	FAGATA	5
LEPIDOPTERA	OECOPHORIDAE	DIURNEA	FAGELLA	16
LEPIDOPTERA	NOCTUIDAE	ANAGRAPHA	FALCIFERA	12
LEPIDOPTERA	TORTRICIDAE	ADOXOPHYES	FASCIATA	5 9
LEPIDOPTERA	PAMPHILIIDAE	CEPHALCIA	FASCIPENNIS	9
ORTHOPTERA	ACRIDIDAE	MELANOPLUS	FEMURRUBRUM	4
LEPIDOPTERA	NOCTUIDAE	ACTEBIA	FENNICA	12
DIPTERA	CULICIDAE	PSOROPHORA	FEROX	5 10 12
LEPIDOPTERA	PYRALIDAE	CADRA	FIGULILELLA	9
LEPIDOPTERA	NOCTUIDAE	LAMPRA	FIMBRIATA	5
LEPIDOPTERA	GEOMETRIDAE	LAMBDINA	FISCELLARIA	12 16
LEPIDOPTERA	GEOMETRIDAE	LAMBDINA	FISCELLARIA LUGUBROSA	12 16
LEPIDOPTERA	GEOMETRIDAE	LAMBDINA	FISCELLARIA SOMNIARIA	12 16
LEPIDOPTERA	NOCTUIDAE	PANOLIS	FLAMMEA	12 16
LEPIDOPTERA	NOCTUIDAE	ANOMIS	FLAVA	12
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	FLAVA	12
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	FRAGILE	12
DIPTERA	CULICIDAE	ANOPHELES	FREEBORNI	12
DIPTERA	COELOPIDAE	COELOPA	FRIGIDA	17
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	FRUGIPERDA	9 12 16
LEPIDOPTERA	ARCTIIDAE	PHRAGMATOBIA	FULIGINOSA	5 9 16
DIPTERA	CULICIDAE	AEDES	FULVUS PALLENS	10
LEPIDOPTERA	LYMANTRIIDAE	LYMANTRIA	FUMIDA FUMIDA	5 12
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	FUMIFERANA	5 9 12 19
LEPIDOPTERA	NOCTUIDAE	DRYOBOTA	FURVA	9 12
DIPTERA	MUSCIDAE	GLOSSINA	FUSCIPES FUSCIPES	17
LEPIDOPTERA	SPHINGIDAE	CELERIO	GALII	12 16
LEPIDOPTERA	NOCTUIDAE	AUTOGRAPHA	GAMMA	5 12
LEPIDOPTERA	NOCTUIDAE	ANTICARSIA	GEMMATILIS	16
HYMENOPTERA	TENTHREDINIDAE	PRISTIPHORA	GENICULATA	12
LEPIDOPTERA	NOTODONTIDAE	NADATA	GIBBOSA	12
LEPIDOPTERA	NOCTUIDAE	AMATHES	GLAREOSA	5
LEPIDOPTERA	ARCTIIDAE	ARDICES	GLATIGNYI	12
LEPIDOPTERA	TORTRICIDAE	ACLERIS	GLOVERANA	12
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	GONOSTIGMA	12
LEPIDOPTERA	NOCTUIDAE	BELLURA	GORTYNOIDES	12
LEPIDOPTERA	GELECHIIDAE	PECTINOPHORA	GOSSYPIELLA	5 12
COLEOPTERA	CURCULIONIDAE	ANTHONOMUS	GRANDIS	10 12
LEPIDOPTERA	GEOMETRIDAE	ABRAXAS	GROSSULARIATA	5 12
LEPIDOPTERA	NOTODONTIDAE	HETEROCAMPA	GUTTIVITA	16
LEPIDOPTERA	SPHINGIDAE	CELERIO	HARMUTHI	16
LEPIDOPTERA	GEOMETRIDAE	EULYPE	HASTATA	9
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	HELENA	13
LEPIDOPTERA	NOCTUIDAE	ANCHOSCELI	HELVOLA	5
HYMENOPTERA	DIPRIONIDAE	DIPRION	HERCYNIAE	12
LEPIDOPTERA	NOTODONTIDAE	CERURA	HERMELINA	12 16
COLEOPTERA	SCARABAEIDAE	MELOLONTHA	HIPPOCASTANI	20
LEPIDOPTERA	GEOMETRIDAE	BISTON	HIRTARIA	12
LEPIDOPTERA	GEOMETRIDAE	BISTON	HISPIDARIA	12
DIPTERA	SCIARIDAE	RHYNCHOSCIARA	HOLLAENDERI	12
DIPTERA	CHIRONOMIDAE	GOELDICHIRONOMUS	HOLOPRASINUS	5 17 19
DIPTERA	CULICIDAE	PSOROPHORA	HORRIDA	10
COLEOPTERA	SCARABAEIDAE	PHYLLOPERTHA	HORTICOLA	19
HYMENOPTERA	BOMBIDAE	BOMBUS	HORTORUM	1
LEPIDOPTERA	GEOMETRIDAE	ANTHELIA	HYPERBOREA	12
LEPIDOPTERA	ARCTIIDAE	ECPANTHERIA	ICASIA	9 12
LEPIDOPTERA	GEOMETRIDAE	MELANOLOPHIA	IMITATA	12
DIPTERA	DROSOPHILIDAE	DROSOPHILA	IMMIGRANS	3 13
LEPIDOPTERA	LYMANTRIIDAE	LYMANTRIA	INCERTA	12
LEPIDOPTERA	NOCTUIDAE	PSEUDOPLUSIA	INCLUDENS	12

ORDER	FAMILY	GENUS	SPECIES	DISEASES
LEPIDOPTERA	ZYGAENIDAE	AGLAOPE	INFAUSTA	5
DIPTERA	CULICIDAE	CULISETA	INORNATA	10
LEPIDOPTERA	PYRALIDAE	PLODIA	INTERPUNCTELLA	9 12
LEPIDOPTERA	NYMPHALIDAE	NYMPHALIS	IO	5 12 16
LEPIDOPTERA	NOCTUIDAE	AGROTIS	IPSILON	12
LEPIDOPTERA	SATURNIIDAE	PSEUDOBUNAEA	IRIUS	17
HYMENOPTERA	TENTHREDINIDAE	TRICHIOCAMPUS	IRREGULARIS	12
LEPIDOPTERA	TORTRICIDAE	ARCHIPPUS	ISSHIKII	19
HYMENOPTERA	PAMPHILIIDAE	CEPHALCIA	ISSIKI	12
LEPIDOPTERA	ARCTIIDAE	HYPOCRITA	JACOBAEAE	5 12
LEPIDOPTERA	NOCTUIDAE	ACHAEA	JANATA	9
LEPIDOPTERA	SATURNIIDAE	DICTYOPLOCA	JAPONICA	5 12
LEPIDOPTERA	PAPILIONIDAE	LUEHDORFIA	JAPONICA	12
LEPIDOPTERA	SPHINGIDAE	THERETRA	JAPONICA	12
LEPIDOPTERA	NYMPHALIDAE	CHARAXES	JASIUS	16
LEPIDOPTERA	PSYCHIDAE	CRYPTOTHELEA	JUNODI	12
LEPIDOPTERA	SPHINGIDAE	CELERIO	KINDERVATERI	16
LEPIDOPTERA	PSYCHIDAE	OIKETICUS	KIRBYI	5
LEPIDOPTERA	PHYCITIDAE	ANAGASTA	KUHNIELLA	12
LEPIDOPTERA	DREPANIDAE	DREPANA	LACERTINARIA	5
ISOPTERA	RHINOTERMITIDAE	COPTOTERMES	LACTEUS	17
LEPIDOPTERA	TORTRICIDAE	PANDEMIS	LAMPROSANA	12
LEPIDOPTERA	LASIOCAMPIDAE	ERIOGASTER	LANESTRIS	5
COLEOPTERA	DERMESTIDAE	DERMESTES	LARDARIUS	12 16
LEPIDOPTERA	COLEOPHORIDAE	COLEOPHORA	LARICELLA	12
LEPIDOPTERA	PYRALIDAE	CRYPTOBLABES	LARICIANA	12
LEPIDOPTERA	NYMPHALIDAE	ARGYNNIS	LATHONIA	16
LEPIDOPTERA	NOCTUIDAE	LITHOPHANE	LEAUTIERI	5
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	LECONTEI	12 16
LEPIDOPTERA	LIMACODIDAE	PARASA	LEPIDA	17
LEPIDOPTERA	PIERIDAE	COLIAS	LESBIA	12
LEPIDOPTERA	NOCTUIDAE	AEDIA	LEUCOMELAS	12
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	LEUCOSTIGMA	5 12 16
LEPIDOPTERA	OLETHREUTIDAE	ARGYROPLOCE	LEUCOTRETA	5
LEPIDOPTERA	NOCTUIDAE	SCOLIOPTERYX	LIBATRIX	5 12
LEPIDOPTERA	SPHINGIDAE	SPHINX	LIGUSTRI	5 12
COLEOPTERA	CERAMBYCIDAE	BATOCERA	LINEOLATA	12
LEPIDOPTERA	NOCTUIDAE	PRODENIA	LITOSIA	12
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	LITTORALIS	5 9 12 16
LEPIDOPTERA	GEOMETRIDAE	SEMIOTHISA	LITURATA	5
DIPTERA	TIPULIDAE	TIPULA	LIVIDA	10
LEPIDOPTERA	TORTRICIDAE	TORTRIX	LOEFLINGIANA	12 16
LEPIDOPTERA	TORTRICIDAE	ARCHIPS	LONGICELLANA	9
LEPIDOPTERA	GEOMETRIDAE	EUPITHECIA	LONGIPALPATA	12
LEPIDOPTERA	ARCTIIDAE	SPILOSOMA	LUBRICIPEDA	5 12
LEPIDOPTERA	NOCTUIDAE	EUPLEXIA	LUCIPARA	9
HYMENOPTERA	BOMBIDAE	BOMBUS	LUCORUM	1
HYMENOPTERA	FORMICIDAE	FORMICA	LUGUBRIS	17
LEPIDOPTERA	SATURNIIDAE	ACTIAS	LUNA	5
LEPIDOPTERA	GEOMETRIDAE	SELENIA	LUNARIA	5
LEPIDOPTERA	NOCTUIDAE	CALOPHASIA	LUNULA	5 12
LEPIDOPTERA	HEPIALIDAE	HEPIALUS	LUPULINUS	5
DIPTERA	CHIRONOMIDAE	CHIRONOMUS	LURIDUS	19
LEPIDOPTERA	ARCTIIDAE	SPILOSOMA	LUTEA	5
LEPIDOPTERA	GEOMETRIDAE	OPISTHOGRAPTIS	LUTEOLATA	12
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	LUTESCENS	12
LEPIDOPTERA	NOCTUIDAE	AGROCHOLA	LYCHNIDIS	5
LEPIDOPTERA	PAPILIONIDAE	PAPILIO	MACHAON	5
LEPIDOPTERA	TORTRICIDAE	HOMONA	MAGNANIMA	5 12
LEPIDOPTERA	SATURNIIDAE	HEMILEUCA	MAIA	16
HEMIPTERA	APHIDIDAE	RHOPALOSIPHUM	MAIDIS	17
LEPIDOPTERA	BOMBYCIDAE	THEOPHILA	MANDARINA	5 12
DIPTERA	BIBIONIDAE	BIBIO	MARCI	10
LEPIDOPTERA	GEOMETRIDAE	BISTON	MARGINATA	16
LEPIDOPTERA	LYMANTRIIDAE	LYMANTRIA	MATHURA AURORA	5 12
LEPIDOPTERA	NOCTUIDAE	MANIA	MAURA	5
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	MAURITIA	12 15
LEPIDOPTERA	NOCTUIDAE	SPODOPTERA	MAURITIA ACRONYCTOIDES	12
LEPIDOPTERA	PYRALIDAE	CNAPHALOCROCIS	MEDINALIS	9
LEPIDOPTERA	SATYRIDAE	DIRA	MEGERA	5
HYMENOPTERA	HALICTIDAE	NOMIA	MELANDERI	17
DIPTERA	DROSOPHILIDAE	DROSOPHILA	MELANOGASTER	3 13 17
DIPTERA	CULICIDAE	CULISETA	MELANURA	5 10
HYMENOPTERA	APIDAE	APIS	MELLIFERA	1 2 6 10 13 15 17 18 21
LEPIDOPTERA	GALLERIIDAE	GALLERIA	MELLONELLA	5 6 10 12 13 16 19
COLEOPTERA	SCARABAEIDAE	MELOLONTHA	MELOLONTHA	6 19 20
LEPIDOPTERA	SATURNIIDAE	AUTOMERIS	MEMUSAE	5
LEPIDOPTERA	ARCTIIDAE	CYCNIA	MENDICA	5 12
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	MENDOSA	12
LEPIDOPTERA	SPHINGIDAE	PSILOGRAMMA	MENEPHRON	9

ORDER	FAMILY	GENUS	SPECIES	DISEASES
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	MERKELI	5
LEPIDOPTERA	NOCTUIDAE	EUXOA	MESSORIA	5 12
LEPIDOPTERA	NOCTUIDAE	PHLOGOPHORA	METICULOSA	5 12
NEUROPTERA	MYRMELEONTIDAE	HAGENOMYIA	MICANS	16
ORTHOPTERA	ACRIDIDAE	LOCUSTA	MIGRATORIA	17
LEPIDOPTERA	GELECHIIDAE	COLEOTECHNITES	MILLERI	9
DIPTERA	SCIARIDAE	RHYNCHOSCIARA	MILLERI	12
LEPIDOPTERA	PSYCHIDAE	MAHASENA	MINUSCULA	12
DIPTERA	SIMULIIDAE	PROSIMULIUM	MIXTUM	5
LEPIDOPTERA	SPHINGIDAE	PACHYSPHINX	MODESTA	5
COLEOPTERA	TENEBRIONIDAE	TENEBRIO	MOLITOR	10 17
LEPIDOPTERA	LYMANTRIIDAE	LYMANTRIA	MONACHA	5 12 16
COLEOPTERA	SCARABAEIDAE	ORYCTES	MONOCEROS	20
LEPIDOPTERA	NOCTUIDAE	DRYOBOTODES	MONOCHROMA	12
HEMIPTERA	CICADELLIDAE	COLLADONUS	MONTANUS	10
DIPTERA	DROSOPHILIDAE	DROSOPHILA	MONTIUM	13
LEPIDOPTERA	ARCTIIDAE	AMSACTA	MOOREI	12 13
LEPIDOPTERA	BOMBYCIDAE	BOMBYX	MORI	5 6 7 8 10 12 13 14 19
DIPTERA	MUSCIDAE	GLOSSINA	MORSITANS CENTRALIS	17
DIPTERA	ITONIDIDAE	SITODIPLOSIS	MOSELLANA	16
ACARINA	TETRANYCHIDAE	TETRANYCHUS	MULTISETIS	17
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	MUNDUS	16
LEPIDOPTERA	TORTRICIDAE	CACOECIA	MURINANA	9 12 16
COLEOPTERA	DERMESTIDAE	ANTHRENUS	MUSEORUM	12 16
DIPTERA	SIMULIIDAE	CNEPHIA	MUTATA	5
LEPIDOPTERA	NOCTUIDAE	HADA	NANA	5
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	NANULUS	16
LEPIDOPTERA	PIERIDAE	PIERIS	NAPI	9
LEPIDOPTERA	LIMACODIDAE	NATADA	NARARIA	9
COLEOPTERA	SCARABAEIDAE	ORYCTES	NASICORNIS	11 20
COLEOPTERA	GYRINIDAE	GYRINUS	NATATOR	13
HYMENOPTERA	PAMPHILIIDAE	ACANTHOLYDA	NEMORALIS	16
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	NEUSTRIA	5 12 16
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	NEUSTRIA TESTACEA	5 12 16
LEPIDOPTERA	NOCTUIDAE	TRICHOPLUSIA	NI	5 9 10 12
LEPIDOPTERA	SATURNIIDAE	HYLESIA	NIGRICANS	12
HYMENOPTERA	BRACONIDAE	CARDIOCHILES	NIGRICEPS	17
LEPIDOPTERA	NOCTUIDAE	AUTOGRAPHA	NIGRISIGNA	12
DIPTERA	CULICIDAE	AEDES	NIGROMACULIS	12
LEPIDOPTERA	CARPOSINIDAE	CARPOSINA	NIPONENSIS	12
HYMENOPTERA	DIPRIONIDAE	DIPRION	NIPPONICA	12
LEPIDOPTERA	NOCTUIDAE	SESAMIA	NONAGRIOIDES	9
LEPIDOPTERA	NOCTUIDAE	RACHIPLUSIA	NU	12 16
LEPIDOPTERA	PYRALIDAE	OSTRINIA	NUBILALIS	17
LEPIDOPTERA	NOCTUIDAE	CATOCALA	NYMPHAEA	12
LEPIDOPTERA	NOCTUIDAE	CATOCALA	NYMPHAGOGA	12
LEPIDOPTERA	LYMANTRIIDAE	PORTHETRIA	OBFUSCATA	12
LEPIDOPTERA	ARCTIIDAE	DIACRISIA	OBLIQUA	9
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	OBSOLETA	12
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	OBTECTUS	12
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	OCCIDENTALIS	12
ORTHOPTERA	GRYLLIDAE	TELEOGRYLLUS	OCEANICUS	13
LEPIDOPTERA	OLETHREUTIDAE	SPILONOTA	OCELLANA	12
LEPIDOPTERA	SPHINGIDAE	SMERINTHUS	OCELLATA	5 12 16
LEPIDOPTERA	SPHINGIDAE	SMERINTHUS	OCELLATA ATLANTICUS	12 16
LEPIDOPTERA	NOCTUIDAE	EUXOA	OCHROGASTER	5 9 12 16
LEPIDOPTERA	PYRALIDAE	NACOLEIA	OCTOSEMA	12
LEPIDOPTERA	YPONOMEUTIDAE	PRAYS	OLEELLUS	16
LEPIDOPTERA	NOCTUIDAE	DIATARAXIA	OLERACEA	5 9
DIPTERA	TIPULIDAE	TIPULA	OLERACEA	10
HYMENOPTERA	TENTHREDINIDAE	NEMATUS	OLFACIENS	12
LEPIDOPTERA	SATURNIIDAE	HEMILEUCA	OLIVIAE	16
LEPIDOPTERA	NOCTUIDAE	DICYCLA	OO	12
LEPIDOPTERA	MEGALOPYGIDAE	MEGALOPYGE	OPERCULARIS	9
LEPIDOPTERA	GELECHIIDAE	PHTHORIMAEA	OPERCULELLA	9 12
LEPIDOPTERA	TORTRICIDAE	ADOXOPHYES	ORANA	9
LEPIDOPTERA	NOCTUIDAE	PLUSIA	ORICHALCEA	12
DIPTERA	SIMULIIDAE	SIMULIUM	ORNATUM	10
LEPIDOPTERA	NOCTUIDAE	PRODENIA	ORNITHOGALLI	12 16
LEPIDOPTERA	NOCTUIDAE	RACHIPLUSIA	OU	12
LEPIDOPTERA	NOCTUIDAE	ALETIA	OXYGALA LUTEOPALLENS	12
HYMENOPTERA	DIPRIONIDAE	DIPRION	PALLIDA	12
LEPIDOPTERA	TORTRICIDAE	AMELIA	PALLORANA	9
LEPIDOPTERA	GEOMETRIDAE	SYNAXIS	PALLULATA	12
DIPTERA	TIPULIDAE	TIPULA	PALUDOSA	10 12 16
LEPIDOPTERA	SATURNIIDAE	COLORADIA	PANDORA	12 16
LEPIDOPTERA	NYMPHALIDAE	ARGYNNIS	PAPHIA	12 16
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	PAPHIA MYLITTA	5 12
DIPTERA	DROSOPHILIDAE	DROSOPHILA	PAULISTORUM	17
DIPTERA	CULICIDAE	CULEX	PECCATOR	10

ORDER	FAMILY	GENUS	SPECIES	DISEASES			
HYMENOPTERA	ARGIDAE	ARGE	PECTORALIS	12			
LEPIDOPTERA	GEOMETRIDAE	PHIGALIA	PEDARIA	12			
LEPIDOPTERA	TINEIDAE	TINEA	PELLIONELLA	5	12		
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	PELTIGERA	12			
LEPIDOPTERA	NOCTUIDAE	PODIOPLUSIA	PEPONIS	12			
NEUROPTERA	CHRYSOPIDAE	CHRYSOPA	PERLA	5	12		
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	PERNYI	5	12	13	16
LEPIDOPTERA	NOCTUIDAE	MELANCHRA	PERSICARIAE	9			
LEPIDOPTERA	TORTRICIDAE	SPARGANOTHIS	PETTITANA	12			
LEPIDOPTERA	LYMANTRIIDAE	NYGMIA	PHAEORRHOEA	16			
LEPIDOPTERA	GEOMETRIDAE	NEPYTIA	PHANTASMARIA	12			
LEPIDOPTERA	TORTRICIDAE	LATHRONYMPHA	PHASEOLI	9			
LEPIDOPTERA	SPHINGIDAE	CELERIO	PHILEUPHORBIAE	16			
LEPIDOPTERA	PIERIDAE	COLIAS	PHILODICE	12	16		
LEPIDOPTERA	LYCAENIDAE	LYCAENA	PHLAEAS	5			
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	PHLOXIPHAGA	12	16		
LEPIDOPTERA	NOCTUIDAE	CERAMICA	PICTA	5	12		
COLEOPTERA	BUPRESTIDAE	MELANOPHILA	PICTA	5	16		
LEPIDOPTERA	SPHINGIDAE	SPHINX	PINASTRI	5	12		
HYMENOPTERA	DIPRIONIDAE	DIPRION	PINDROWI	12			
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	PINI	12	16		
HYMENOPTERA	DIPRIONIDAE	DIPRION	PINI	12			
LEPIDOPTERA	GEOMETRIDAE	BUPALUS	PINIARIUS	5	12	16	
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	PINUS	12			
DIPTERA	CULICIDAE	CULEX	PIPIENS	3			
DIPTERA	CULICIDAE	CULEX	PIPIENS QUINQUEFASCIATUS	12			
LEPIDOPTERA	THAUMETOPOEIDAE	THAUMETOPOEA	PITYOCAMPA	5	9	12	
LEPIDOPTERA	GEOMETRIDAE	ANAITIS	PLAGIATA	5	12		
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	PLAGIATA	12			
LEPIDOPTERA	ARCTIIDAE	PARASEMIA	PLANTAGINIS	5			
COLEOPTERA	SCARABAEIDAE	PHYLLOPHAGA	PLEEI	19			
LEPIDOPTERA	DANAIDAE	DANAUS	PLEXIPPUS	5	16		
DIPTERA	CHIRONOMIDAE	CHIRONOMUS	PLUMOSUS	5	10		
LEPIDOPTERA	LASIOCAMPIDAE	MALACOSOMA	PLUVIALE	12			
LEPIDOPTERA	PAPILIONIDAE	PAPILIO	PODALIRIUS	12			
LEPIDOPTERA	LASIOCAMPIDAE	GONOMETA	PODOCARPI	13			
LEPIDOPTERA	NYMPHALIDAE	NYMPHALIS	POLYCHLOROS	16			
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	POLYPHEMUS	5	12	16	
HYMENOPTERA	DIPRIONIDAE	DIPRION	POLYTOMA	12			
LEPIDOPTERA	GEOMETRIDAE	ALSOPHILA	POMETARIA	5	9	12	
LEPIDOPTERA	OLETHREUTIDAE	LASPEYRESIA	POMONELLA	9	16		
LEPIDOPTERA	SPHINGIDAE	LAOTHOE	POPULI	5	12		
LEPIDOPTERA	GEOMETRIDAE	PROTOBOARMIA	PORCELARIA INDICATARIA	12			
COLEOPTERA	SCARABAEIDAE	ANOPLOGNATHUS	POROSUS	19			
LEPIDOPTERA	NOCTUIDAE	PANTHEA	PORTLANDIA	12			
LEPIDOPTERA	TORTRICIDAE	EPIPHYAS	POSTVITTANA	12			
LEPIDOPTERA	LASIOCAMPIDAE	COSMOTRICHE	POTATORIA	12			
LEPIDOPTERA	NOCTUIDAE	PRODENIA	PRAEFICA	12			
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	PRATTI BANKSIANAE	12			
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	PRATTI PRATTI	15			
LEPIDOPTERA	NOCTUIDAE	AUTOGRAPHA	PRECATIONIS	12			
LEPIDOPTERA	THAUMETOPOEIDAE	THAUMETOPOEA	PROCESSIONEA	5	12		
LEPIDOPTERA	NOCTUIDAE	TRIPHAENA	PRONUBA	5			
LEPIDOPTERA	SPHINGIDAE	PROSERPINUS	PROSERPINA	16			
LEPIDOPTERA	NOCTUIDAE	DRYOBOTA	PROTEA	12			
COLEOPTERA	SCARABAEIDAE	SERICESTHIS	PRUINOSA	10			
LEPIDOPTERA	SATURNIIDAE	SAMIA	PRYERI	5	12		
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	PSEUDABIETIS	12			
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	PSEUDOCONSPERSA	12			
DIPTERA	DROSOPHILIDAE	DROSOPHILA	PSEUDOOBSCURA	17			
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	PSEUDOTSUGATA	5	12	16	
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	PUDIBUNDA	5	12	15	
LEPIDOPTERA	PYRALIDAE	DICHOCROCIS	PUNCTIFERALIS	12			
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	PUNCTIGERA	9	12		
LEPIDOPTERA	ARCTIIDAE	DIACRISIA	PURPURATA	5	12		
LEPIDOPTERA	NOCTUIDAE	PAPAIPEMA	PURPURIFASCIA	9			
LEPIDOPTERA	SATURNIIDAE	SATURNIA	PYRI	5	12	16	
DIPTERA	CULICIDAE	ANOPHELES	QUADRIMACULATUS	10	14		
LEPIDOPTERA	ARCTIIDAE	EUPLAGIA	QUADRIPUNCTARIA	5			
LEPIDOPTERA	GEOMETRIDAE	ENNOMOS	QUERCARIA	12			
LEPIDOPTERA	LASIOCAMPIDAE	GASTROPACHA	QUERCIFOLIA	5			
LEPIDOPTERA	LASIOCAMPIDAE	GASTROPACHA	QUERCIFOLIA CERRIDIFOLIA	5	12		
LEPIDOPTERA	GEOMETRIDAE	ENNOMOS	QUERCINARIA	12			
LEPIDOPTERA	LASIOCAMPIDAE	LASIOCAMPA	QUERCUS	5			
LEPIDOPTERA	SPHINGIDAE	MANDUCA	QUINQUEMACULATA	9			
LEPIDOPTERA	PIERIDAE	PIERIS	RAPAE	5	9	12	16
LEPIDOPTERA	PIERIDAE	PIERIS	RAPAE CRUCIVORA	5	9	12	
LEPIDOPTERA	LIMACODIDAE	THOSEA	RECTA	17			
DIPTERA	CULICIDAE	CULEX	RESTUANS	17			
LEPIDOPTERA	TORTRICIDAE	ADOXOPHYES	RETICULANA	5	12		

ORDER	FAMILY	GENUS	SPECIES	DISEASES			
LEPIDOPTERA	PIERIDAE	GONEPTERYX	RHAMNI	5			
COLEOPTERA	SCARABAEIDAE	ORYCTES	RHINOCEROS	11			
LEPIDOPTERA	ARCTIIDAE	PERICALLIA	RICINI	9	12		
LEPIDOPTERA	SATURNIIDAE	SAMIA	RICINI	5	12	13	16
LEPIDOPTERA	GEOMETRIDAE	BISTON	ROBUSTUM	12			
LEPIDOPTERA	TORTRICIDAE	CHORISTONEURA	ROSACEANA	12			
HYMENOPTERA	MEGACHILIDAE	MEGACHILE	ROTUNDATA	17			
LEPIDOPTERA	LASIOCAMPIDAE	MACROTHYLACIA	RUBI	12			
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	RUBRESCENS	9			
HYMENOPTERA	BOMBIDAE	BOMBUS	RUDERARIS	1			
LEPIDOPTERA	PYRALIDAE	WITLESIA	SABULOSELLA	10			
LEPIDOPTERA	CRAMBIDAE	DIATRAEA	SACCHARALIS	9			
LEPIDOPTERA	LYMANTRIIDAE	STILPNOTIA	SALICIS	12	16		
DIPTERA	CULICIDAE	CULEX	SALINARIUS	5	10	12	
LEPIDOPTERA	GEOMETRIDAE	OURAPTERYX	SAMBUCARIA	5			
ORTHOPTERA	ACRIDIDAE	MELANOPLUS	SANGUINIPES	4	12	19	
DIPTERA	CULICIDAE	URANOTAENIA	SAPPHIRINA	12	17		
LEPIDOPTERA	NOCTUIDAE	EUPSILIS	SATELITIA	9			
LEPIDOPTERA	NYMPHALIDAE	POLYGONIA	SATYRUS	12			
LEPIDOPTERA	NOCTUIDAE	PERIDROMA	SAUCIA	9	12	16	
LEPIDOPTERA	NOCTUIDAE	PLATHYPENA	SCABRA	9			
LEPIDOPTERA	EPIPASCHIIDAE	TETRALOPHA	SCORTEALIS	12	15		
LEPIDOPTERA	GEOMETRIDAE	CLEORA	SECUNDARIA	17			
LEPIDOPTERA	NOCTUIDAE	AGROTIS	SEGETUM	5	9	12	
LEPIDOPTERA	NOCTUIDAE	SYNOGRAPHA	SELECTA	12			
LEPIDOPTERA	SATURNIIDAE	ACTIAS	SELENE	5	13		
LEPIDOPTERA	LYMANTRIIDAE	DASYCHIRA	SELENITICA	16			
LEPIDOPTERA	SATURNIIDAE	ANISOTA	SENATORIA	16			
LEPIDOPTERA	NOCTUIDAE	PSEUDALETIA	SEPARATA	9	12	13	
LEPIDOPTERA	NOCTUIDAE	HADENA	SERENA	5			
LEPIDOPTERA	GEOMETRIDAE	PTYCHOPODA	SERIATA	12	16		
DIPTERA	TACHINIDAE	UGYMYIA	SERICARIAE	12			
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	SERTIFER	12	16	17	
LEPIDOPTERA	GEOMETRIDAE	SEMIOTHISA	SEXMACULATA	9			
LEPIDOPTERA	SPHINGIDAE	MANDUCA	SEXTA	9	12		
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	SIBIRICUS	9			
DIPTERA	CULICIDAE	AEDES	SIERRENSIS	10	12		
DIPTERA	CULICIDAE	ORTHOPODOMYIA	SIGNIFERA	17			
COLEOPTERA	SCARABAEIDAE	GEOTRUPES	SILVATICUS	19			
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	SIMILIS	5	12		
LEPIDOPTERA	GEOMETRIDAE	PERIBATODES	SIMPLICIARIA	12			
DIPTERA	CULICIDAE	WYEOMYIA	SMITHII	12			
DIPTERA	CULICIDAE	AEDES	SOLLICITANS	5	10	12	
COLEOPTERA	SCARABAEIDAE	AMPHIMALLON	SOLSTITIALIS	19			
LEPIDOPTERA	NOCTUIDAE	HADENA	SORDIDA	9	12		
COLEOPTERA	SCARABAEIDAE	DASYGNATHUS	SP.	19			
TRICHOPTERA	LIMNEPHILIDAE	NEOPHYLAX	SP.	12			
COLEOPTERA	SCARABAEIDAE	OPOGONIA	SP.	10			
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	SPECTABILIS	5	12		
LEPIDOPTERA	PYRALIDAE	DIORYCTRIA	SPLENDIDELLA	17			
DIPTERA	CULICIDAE	ANOPHELES	STEPHENSI	3	5		
COLEOPTERA	SCARABAEIDAE	GEOTRUPES	STERCOROSUS	19			
DIPTERA	CULICIDAE	AEDES	STICTICUS	10			
NEUROPTERA	HEMEROBIIDAE	HEMEROBIUS	STIGMA	5	12		
DIPTERA	CULICIDAE	AEDES	STIMULANS	10			
LEPIDOPTERA	GEOMETRIDAE	BISTON	STRATARIA	12			
HEMIPTERA	DELPHACIDAE	LAODELPHAX	STRIATELLA	10			
LEPIDOPTERA	GEOMETRIDAE	SELIDOSEMA	SUAVIS	12			
LEPIDOPTERA	ARCTIIDAE	SPILARCTIA	SUBCARNEA	5	12		
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	SUBFLAVA	12			
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	SUBFLEXA	12			
COLEOPTERA	LUCANIDAE	FIGULUS	SUBLAEVIS	19			
DIPTERA	CULICIDAE	ANOPHELES	SUBPICTUS	17			
LEPIDOPTERA	NOCTUIDAE	FELTIA	SUBTERRANEA	9			
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	SUPERANS	5			
LEPIDOPTERA	PYRALIDAE	CHILO	SUPPRESSALIS	9	10	12	
COLEOPTERA	BUPRESTIDAE	AGRILUS	SUVOROVI POPULNEUS	5			
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	SWAINEI	12			
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	TAEDAE LINEARIS	12			
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	TAEDAE TAEDAE	12	15		
DIPTERA	CULICIDAE	AEDES	TAENIORHYNCHUS	5	10	12	13
LEPIDOPTERA	NYMPHALIDAE	VANESSA	TAMMEAMEA	16			
DIPTERA	CULICIDAE	CULEX	TARSALIS	5	12	13	
COLEOPTERA	SCARABAEIDAE	APHODIUS	TASMANIAE	13	19		
ACARINA	TETRANYCHIDAE	TETRANYCHUS	TELARIUS	17			
DIPTERA	CHIRONOMIDAE	CHIRONOMUS	TENTANS	12	17	19	
LEPIDOPTERA	LYMANTRIIDAE	EUPROCTIS	TERMINALIS	16			
HYMENOPTERA	BOMBIDAE	BOMBUS	TERRESTRIS	1			
LEPIDOPTERA	NOCTUIDAE	PRODENIA	TERRICOLA	12			
DIPTERA	CULICIDAE	CULEX	TERRITANS	5	10	17	

ORDER	FAMILY	GENUS	SPECIES	DISEASES					
LEPIDOPTERA	LYONETIIDAE	BUCCULATRIX	THURBERIELLA	12					
LEPIDOPTERA	SPHINGIDAE	DILINA	TILTAE	5					
LEPIDOPTERA	GEOMETRIDAE	ERANNIS	TILIARIA	5	12				
LEPIDOPTERA	GEOMETRIDAE	PHIGALIA	TITEA	12					
DIPTERA	CULICIDAE	AEDES	TORMENTOR	12					
LEPIDOPTERA	PYRALIDAE	PARAMYELOIS	TRANSITELLA	12					
LEPIDOPTERA	SATURNIIDAE	HEMILEUCA	TRICOLOR	12	16				
LEPIDOPTERA	LASIOCAMPIDAE	LASIOCAMPA	TRIFOLII	12					
LEPIDOPTERA	LIMACODIDAE	DARNA	TRIMA	9	13				
DIPTERA	CULICIDAE	AEDES	TRISERIATUS	12	17				
DIPTERA	ITONIDIDAE	CONTARINIA	TRITICI	16					
COLEOPTERA	SCARABAEIDAE	PERICOPTUS	TRUNCATUS	13					
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	TURBATA	12					
LEPIDOPTERA	NOCTUIDAE	ADRIS	TYRANNUS AMURENSIS	5					
ACARINA	TETRANYCHIDAE	PANONYCHUS	ULMI	13					
LEPIDOPTERA	HEPIALIDAE	WISEANA	UMBRACULATA	9	12	19			
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	UNDANS	5	12				
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	UNDANS FLAVEOLA	12					
LEPIDOPTERA	NOCTUIDAE	MOCIS	UNDATA	5					
LEPIDOPTERA	NOCTUIDAE	PSEUDALETIA	UNIPUNCTA	5	9	10	12	13	16
LEPIDOPTERA	NYMPHALIDAE	AGLAIS	URTICAE	5	6	12	16		
ORTHOPTERA	ACRIDIDAE	SCHISTOCERCA	VAGA	4					
LEPIDOPTERA	GEOMETRIDAE	ERANNIS	VANCOUVERENSIS	12					
LEPIDOPTERA	NYMPHALIDAE	AGRAULIS	VANILLAE	12					
LEPIDOPTERA	ANTHELIDAE	ANTHELA	VARIA	12					
LEPIDOPTERA	TORTRICIDAE	ACLERIS	VARIANA	12					
DIPTERA	CULICIDAE	PSOROPHORA	VARIPES	10	12				
LEPIDOPTERA	TORTRICIDAE	ARGYROTAENIA	VELUTINANA	9					
LEPIDOPTERA	GEOMETRIDAE	ENYPIA	VENATA	12					
LEPIDOPTERA	GEOMETRIDAE	PALEACRITA	VERNATA	5	12				
COLEOPTERA	SCARABAEIDAE	RHOPAEA	VERRAUXI	19					
LEPIDOPTERA	SPHINGIDAE	CELERIO	VESPERTILIO	16					
LEPIDOPTERA	LYMANTRIIDAE	ORGYIA	VETUSTA	12					
DIPTERA	CULICIDAE	AEDES	VEXANS	10					
LEPIDOPTERA	ARCTIIDAE	ARCTIA	VILLICA	5	12				
COLEOPTERA	SCARABAEIDAE	ANOXIA	VILLOSA	19					
HYMENOPTERA	TENTHREDINIDAE	TRICHIOCAMPUS	VIMINALIS	12					
LEPIDOPTERA	NOTODONTIDAE	CERURA	VINULA	5					
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	VIRESCENS	5	12	16			
HYMENOPTERA	DIPRIONIDAE	NEODIPRION	VIRGINIANA	12					
LEPIDOPTERA	ARCTIIDAE	DIACRISIA	VIRGINICA	12					
LEPIDOPTERA	ARCTIIDAE	APANTESIS	VIRGO	16					
LEPIDOPTERA	TORTRICIDAE	TORTRIX	VIRIDANA	5	12	16			
DIPTERA	DROSOPHILIDAE	DROSOPHILA	VIRILIS	17					
DIPTERA	CALLIPHORIDAE	CALLIPHORA	VOMITORIA	10	12	16			
LEPIDOPTERA	NOCTUIDAE	DIPAROPSIS	WATERSI	12					
LEPIDOPTERA	THAUMETOPOEIDAE	THAUMETOPOEA	WILKINSONI	5	12				
DIPTERA	DROSOPHILIDAE	DROSOPHILA	WILLISTONI	17					
LEPIDOPTERA	LYMANTRIIDAE	PORTHESIA	XANTHOCAMPA	5					
LEPIDOPTERA	NOCTUIDAE	ANTITYPE	XANTHOMISTA	5					
LEPIDOPTERA	HEPIALIDAE	METAHEPIALUS	XENOCTENIS	13					
LEPIDOPTERA	YPONOMEUTIDAE	PLUTELLA	XYLOSTELLA	9	12				
LEPIDOPTERA	LASIOCAMPIDAE	DENDROLIMUS	YAMADAI	5	12				
LEPIDOPTERA	SATURNIIDAE	ANTHERAEA	YAMAMAI	12	16				
LEPIDOPTERA	NOCTUIDAE	HELIOTHIS	ZEA	5	9	12	13		
COLEOPTERA	SCARABAEIDAE	COSTELYTRA	ZEALANDICA	10					
LEPIDOPTERA	PYRALIDAE	ACROBASIS	ZELLERI	19					

TABLE 1--ALPHABETICAL LIST (BY SPECIFIC NAMES) O

SYNONYMS	NAMES ACCEPTED IN HOST LIST
AMERICANUM (NEODIPRION)	TAEDAE TAEDAE (NEODIPRION)
ANASTOMOSIS (CLOSTERA)	ANASTOMOSIS (PYGAERA)
ANASTOMOSIS (MELALOPHA)	ANASTOMOSIS (PYGAERA)
AUXILIARIS (CHORIZAGROTIS)	AUXILIARIS (EUXOA)
BIFIDA (CERURA)	HERMELINA (CERURA)
BRASSICAE (AUTOGRAPHA)	NI (TRICHOPLUSIA)
BRASSICAE (BARATHRA)	BRASSICAE (MAMESTRA)
BRASSICAE (PLUSIA)	NI (TRICHOPLUSIA)
CAMPESTRIS (LYDA)	ABIETIS (CEPHALCIA)
CAUTELLA (EPHESTIA)	CAUTELLA (CADRA)
CECROPIA (PLATYSAMIA)	CECROPIA (HYALOPHORA)
CHALCYTES (PLUSIA)	CHALCITES (CHRYSODEIXIS)
CHAMPA (TRICHOSEA)	CHAMPA (MOMA)
CONTRACTA (SCOPELODES)	CONTRACTA (BEMBECIA)
CYNTHIA (PHILOSAMIA)	CYNTHIA (SAMIA)
CYNTHIA PRYERI (PHILOSAMIA)	PRYERI (SAMIA)
CYTHEREA CAPENSIS (NUDAURELIA)	CYTHEREA CYTHEREA (NUDAURELIA)
DISPAR (LYMANTRIA)	DISPAR (PORTHETRIA)
EXIGUA (LAPHYGMA)	EXIGUA (SPODOPTERA)
FAGELLA (CHIMBACE)	FAGELLA (DIURNEA)
FASCIATA (DROSOPHILA)	MELANOGASTER (DROSOPHILA)
FRUGIPERDA (LAPHYGMA)	FRUGIPERDA (SPODOPTERA)
GAMMA (PLUSIA)	GAMMA (AUTOGRAPHA)
GRISEANA (EUCOSMA)	DINIANA (ZEIRAPHERA)
HYPOTROPHICA (LYDA)	ABIETIS (CEPHALCIA)
IMPARILIS (SPILARCTIA)	LUBRICIPEDA (SPILOSOMA)
JUNODI (ACANTHOPSYCHE)	JUNODI (CRYPTOTHELEA)
LARICIPHILA (CEPHALEIA)	ALPINA (CEPHALCIA)

OME OF THE MOST COMMON SYNONYMS OF HOST SPECIES

SYNONYMS	NAMES ACCEPTED IN HOST LIST
LITURA (PRODENIA)	LITTORALIS (SPODOPTERA)
MARGARITOSA (PERIDROMA)	SAUCIA (PERIDROMA)
MENTHASTRI (SPILOSOMA)	LUBRICIPEDA (SPILOSOMA)
MILLERI (RECURVARIA)	MILLERI (COLEOTECHNITES)
MURINANA (CHORISTONEURA)	MURINANA (CACOECIA)
NARARIA (SUSICA)	NARARIA (NATADA)
OLERACEA (MAMESTRA)	OLERACEA (DIATARAXIA)
OPERCULELLA (GNORIMOSCHEMA)	OPERCULELLA (PHTHORIMAEA)
PAVONIA MAJOR (SATURNIA)	PYRI (SATURNIA)
PHASEOLI (CYDIA)	PHASEOLI (LATHRONYMPHA)
PIPIENS FATIGANS (CULEX)	PIPIENS QUINQUEFASCIATUS (CULEX)
POMONELLA (CARPOCAPSA)	POMONELLA (LASPEYRESIA)
PRATENSIS (TENTHREDO)	NEMORALIS (ACANTHOLYDA)
PSEUDOTSUGATA (HEMEROCAMPA)	PSEUDOTSUGATA (ORGYIA)
QUINQUEMACULATA (PROTOPARCE)	QUINQUEMACULATA (MANDUCA)
RUFUS (LOPHYRUS)	SERTIFER (NEODIPRION)
SEPARATA (LEUCANIA)	SEPARATA (PSEUDALETIA)
SERIATA (STERRHA)	SERIATA (PTYCHOPODA)
SERTIFERA (TENTHREDO)	SERTIFER (NEODIPRION)
SEXTA (PROTOPARCE)	SEXTA (MANDUCA)
STELLATA (LYDA)	NEMORALIS (ACANTHOLYDA)
UNDANS (METANASTRIA)	UNDANS (DENDROLIMUS)
YAMADAI (KUNUGIA)	YAMADAI (DENDROLIMUS)
YPSILON (AGROTIS)	IPSILON (AGROTIS)

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ABSTRACT ONLY	
AUTHOR LIST CHECK	
SPECIES LIST CHECK	
NEW HOST RECORD	
NEW DISEASE RECORD	

INITIALS		

AUTH

YEAR

TITL

REF

FAM

GEN

SPEC

PATH

SUBJ

CARD

MART-FAM

11/5/74

REFERENCE SYSTEM

Insect Virus Catalogue

SHEETS	
REPRINT	
ABSTRACT ONLY	
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Key.--Alphabetical list of diseases and disease groups, with their respective code numbers

DISEASE NAME	CODE
ACUTE PARALYSIS	1
CHRONIC PARALYSIS	2
CO2 SENSITIVITY	3
CRYSTALLINE-ARRAY VIROSIS	4
CYTOPLASMIC POLYHEDROSIS	5
DENSONUCLEOSIS	6
FLACHERIE	7
GATTINE	8
GRANULOSIS	9
HAIRLESS-BLACK SYNDROME	21
IRIDESCENT VIROSIS	10
MALAYA DISEASE	11
NUCLEOPOLYHEDROSIS	12
OTHER NONOCCLUDED-VIRUS DISEASE	13
OTHER OCCLUDED-VIRUS DISEASE	14
PARALYSIS	15
POLYHEDROSIS	16
PRESUMED VIROSIS	17
SACBROOD	18
SPHEROIDOSIS	19
WATERY DISINTEGRATION	20

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Developing and evaluating alternative methods and levels of resource management.
3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research are made available promptly. Project headquarters are at:

Fairbanks, Alaska	Portland, Oregon
Juneau, Alaska	Olympia, Washington
Bend, Oregon	Seattle, Washington
Corvallis, Oregon	Wenatchee, Washington
La Grande, Oregon	

Mailing address: *Pacific Northwest Forest and Range Experiment Station*
P.O. Box 3141
Portland, Oregon 97208

GPO 998-259

The FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

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